MAINTENANCE PERFORMANCE SYSTEM (ORGANIZATIONAL)
TRAINING GUIDELINES APPLIED TO SELECTED OJT TASKS

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AD A138439

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January 1984

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Research Note 84-11	2. GOVT ACCESSION NO. AD-A138 439	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Maintenance Performance System—Organizational Training Guidelines Applied to Selected OJT Tasks		5. TYPE OF REPORT & PERIOD COVERED Contractor Report
		6. PERFORMING ORG. REPORT NUMBER TR465-10
7. AUTHOR(s) Walter R. Harper & Marvin C. McCallum		8. CONTRACT OR GRANT NUMBER(s) MDA 903-81-C-0032
9. PERFORMING ORGANIZATION NAME AND ADDRESS Anacapa Sciences, Inc. Drawer Q Santa Barbara, CA 93102		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q263743A794
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Research Institute for the Behavioral & Social Sciences 5001 Eisenhower Ave. Alexandria, VA 22333		12. REPORT DATE January 1984
		13. NUMBER OF PAGES 76
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This project was monitored technically by Dr. Michael Drillings and Dr. Melissa Berkowitz

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Maintenance, Management Information System, Maintenance Training

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this effort is to develop the Maintenance Performance System-Organizational (MPS-O) which is an integrated system for measuring maintenance performance, diagnosing performance problems, taking corrective actions, and providing training. This report describes a systematic approach to identification of the training guidelines that will be incorporated into a model of the process of on-the-job training in the organizational maintenance environment.

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INTRODUCTION

This report identifies and provides background on those training guidelines that will govern the application of OJT to Army organizational-level maintenance tasks. The emphasis on OJT is one component of an ongoing program for development and implementation of a performance system to combat maintenance performance problems.

These problems were identified and combined into five major categories-- command emphasis, management information, management proficiency, application of resources, and technical proficiency. Descriptions of the specific problems, references on the source material that helped identify the problems, and the rationale behind their assignment to one of the five categories is contained in a previous report (Harris, 1981).

That report discussed the potential of improving maintenance performance by emphasis on solving the problems represented by the five categories above. On-the-job training has obvious relationships to the categories of application of resources and technical proficiency. The work described here was done within the context of these relationships.

OJT is a key component contributing to the acceptance and success of the MPS(O) (Maintenance Performance System (Organizational)), although improving OJT is not the only, or primary, purpose of MPS(O) development. The primary goal of MPS(O) development is to improve maintenance performance--not to develop training programs. The MPS(O) will improve maintenance by application of management techniques and procedures based on unique information provided by the system.

To be fully effective, the MPS(O) must provide a framework for improving maintenance skills and knowledge at the crew and mechanic levels. These men represent the level where repair skills and knowledge meet the repair problem face-to-face.

Improved techniques of OJT to enhance maintenance performance skills can be incorporated directly into the MPS(O), together with information on training

resources. That is, the training deficiency indicators which are powerful by-products of MPS(O) operation will indicate who needs training on what tasks, how the training should be done, and what training resources are needed and available at the unit level. An additional advantage is that the "trainers," who are not usually skilled professional instructors, will have a specific format for imparting technical information based on sound training guidelines derived from the training research literature.

WHAT IS ON-THE-JOB TRAINING?

The answer is not self-evident since the actual parameters of OJT are seldom well defined.

There is confusion about the two on-the-job training approaches--supervised and structured OJT and on-the-job experience (OJE). They are not synonymous. Note these similarities and differences:

- Both approaches are used in the shop during the course of routine maintenance/repair work. OJE takes place entirely in the shop but OJT may involve additional, corollary training outside of the shop environment.

- Both OJT and OJE are closely supervised.

- Both involve "hands-on" practice by the trainee, performance evaluation and subsequent record-keeping.

- Both approaches use "real" repair jobs on "real" equipment as a training resource with appropriate shop tools, technical manuals, and test equipment.

- In both approaches, trainees are aware that training is occurring and are encouraged to treat the repair job as a learning experience.

The differences are clear-cut but somewhat subtle. OJT involves the use of training materials (appropriate to the repair), which are designed and available for use at the unit level. The sequence and content of the training method are in response to training needs identified for specific tasks. In other words, OJT is conducted according to a plan embodying defined objectives and goals--that is, the training and its associated elements are structured.

On-the-job experience is not structured. Since breakdowns cannot usually be predicted, trainees must take what jobs appear and try to learn them as well as possible. Training plans cannot be developed, materials cannot be pre-assembled and NCO-supervisors/instructors cannot be pre-assigned.

For purposes of this project, then, OJT is defined in terms of the attributes listed above.

WHY OJT IS EMPHASIZED

Army policy has dictated that technical training is primarily a unit responsibility. Realistically, unit leaders should not expect the training pipeline to provide crewmen and mechanics who are completely qualified in their MOS. Graduates from AIT schools have received training on those common skills and knowledge each soldier must know for survival, but have received training on only a small proportion of the technical tasks needed to be technically proficient.

One estimate is that only about 15 percent of the technical tasks in an MOS are covered via "hands-on" training in AIT schools. Thus, the average AIT graduate is only qualified at the "apprentice" or "helper" level when he arrives at the unit. Hence, the emphasis on OJT.

TECHNICAL APPROACH

To provide a baseline for developing a set of training guidelines for OJT in the MPS(O), a review was conducted of previously identified maintenance tasks and the associated detailed steps needed to perform each task on specific vehicles. These performance steps were subsequently categorized by the types of action descriptors for each maintenance procedure. Twenty-five of these procedural actions were identified and described.

Two separate bodies of training and learning literature were used as sources for the development of OJT guidelines. Selected items, reviewed in detail from these sources, were research results from experimental work on learning and training, and reports on worthwhile training guidelines described in educational and learning theory textbooks.

Forty-four behavior-related maintenance training topics were identified and grouped into eight behavioral element categories. Maintenance procedural actions were matched against these behavioral categories and a systematic sequence developed for use of combinations of the behavioral elements in OJT. The results from the technical approach—i.e., the recommended ways to incorporate the behavioral and training guidelines into a training environment, are discussed in detail. The technical approach is shown graphically in Figure 1.

ORGANIZATION OF THE REPORT

This report is organized in three parts. Part I contains a review of previously identified maintenance tasks and related task performance steps. This section also contains a discussion of the "clustering" of performance steps related to those elements of behavior used to identify appropriate training guidelines.

Part II describes the identification and listing of training guidelines related to eight behavioral elements of the procedural actions used to conduct maintenance and repairs.

Part III presents a topic summary of the research findings from which the behavioral analysis and training guidelines were derived. References to the research and training literature are contained in two appendices. Appendix A lists the key research sources used to develop training guidelines. These sources were mostly derived from the experimental research literature and are cited appropriately in the report. Some of the concepts used are discussed in formal educational or learning theory texts. These are also listed in Appendix A. Appendix B lists virtually the same sources but with an annotated summary of each key reference for reader convenience.

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                       │  INTO OJT MODEL*    │
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*Under development

Figure 1.   Key steps in technical approach.

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PART I: DEVELOPMENT OF TRAINING GUIDELINES

This section discusses the review and categorization of organizational maintenance tasks for which OJT methods are to be developed. This review led to specification of the behavioral elements required to complete a maintenance task.

Harper, Rugge, and Dyck (1981) have identified critical corrective and preventive maintenance tasks performed by the MOS's listed below on two items of equipment, i.e., the M60A1 tank and the M113 "family" of vehicles.

- MOS 63N, M60A1 Automotive Mechanic
- MOS 45N, M60A1 Turret Mechanic
- MOS 63T, IFV Automotive Mechanic
- MOS 45T, IFV Turret Mechanic
- MOS 19D, Cavalry Scout/M113 Driver
- MOS 19E, Tank Crewman
- MOS 19F, Tank Driver
- MOS 11C, Indirect Fire Infantryman/M113 Driver

Harper et al. also identified the key performance steps required to complete each of the maintenance tasks. The review of the maintenance tasks reported here included additional analysis of these performance steps. The analysis involved summarizing and tabulating the performance steps by the actions involved in completing needed procedures for maintenance tasks. These procedural actions were described in operational terms reflecting the kind of work performed, e.g., adjust, align, assemble, lubricate, and the like.

Sets of the behavioral elements needed to complete each procedural action were identified and matched to each action. The training literature suggested ways in which the behavioral elements could be transformed into training guidelines. Figure 1, portraying the technical approach, illustrates the sequence of events for development of the training guidelines.

SUMMARY AND DEFINITION OF PROCEDURAL ACTIONS

The performance steps for maintenance tasks previously identified were summarized and defined in generic terms so that the different skills to be taught via OJT could be specified and listed in logical sets. The job tasks identified by

Harper et al. did not, of course, include all job tasks performed by all organizational-level maintenance personnel; however, it is assumed that the specific performance steps identified represent an adequate sample of performance steps required to conduct organizational-level maintenance.

Summarizing maintenance task performance steps for all maintenance tasks being considered resulted in the identification of 25 types of procedural actions. Each type of procedural action is listed in Table 1 with a general definition and an associated operational example.

SPECIFICATION OF BEHAVIORAL ELEMENTS

The term **behavioral element** is defined as an activity or skill classified by those psychological behaviors required for its performance. Specifying such behavioral elements was accomplished by analyzing the relationships between previously developed task taxonomies and the maintenance task performance steps.

Researchers who have suggested task taxonomies based upon operational definitions of procedural actions similar to those related to behavioral task elements in the present discussion include Aagard & Braby, 1976; Meister, 1971; and Shuell, 1980. Other taxonomies are implicit in the ways authors of texts on learning, memory, and cognition organize their discussion of the topics (e.g., Adams, 1980; Ellis, 1978; Hulse, Deese, & Egeth, 1975; Kintisch, 1970; Marx, 1970; Melton, 1964; Saltz, 1971). The taxonomies and topic organizations of each of these authors were reviewed for their applicability to the maintenance performance steps we have identified. The eight behavioral elements listed and defined in Table 2 were derived from this review.

Each behavioral element defined in Table 2 was selected whereby each element could be identified by behavioral action or type of psychological process required for task performance, and also be related directly to one or more of the maintenance task procedural actions. (Note that the set of behavioral task elements shown in Table 2 will not meet the requirements for all military job tasks since it is tailored to the specific requirements of organizational maintenance tasks on tracked vehicles.)

TABLE 1

DEFINITIONS AND OPERATIONAL EXAMPLES OF MAINTENANCE
TASK PROCEDURAL ACTIONS

	PROCEDURAL ACTION	DEFINITION	OPERATIONAL EXAMPLE
1.	ADJUST, ALIGN, POSITION	To bring to a more satisfactory state; to bring from out-of-tolerance to an in-tolerance condition.	● Adjust adjusting screw by torquing and "backing off." ● Align boresight cross with target. ● Position steering levers (for brake band adjustment).
2.	ASSEMBLE	To connect unit parts into a sub-assembly or entity.	● Assemble sealing rings and retaining ring in evacuator chamber group.
3.	ATTACH	To join one component to another.	● Attach elbow to replenisher.
4.	BLOCK-UP	To prevent wheels/tracks from moving by temporarily installing a wedge or jamming block.	● Block tank front and rear.
5.	BLEED	To extract from; to release some, or all, of a liquid or gas from its container.	● Bleed manual elevation system.
6.	BREAK	To separate by force.	● Break track to replace faulty link.
7.	CHARGE, PRIME	To fill a container or receptacle up to a specified level.	● Prime manual elevation accumulator.
8.	CLEAR	To make a gun safe by removing unfired rounds from chamber.	● Clear gun before commencing stripdown.
9.	CHECK	Perform specified operations to ensure equipment is functioning to a standard.	● Check temperature of wheel hubs and shock absorbers. ● Test hydraulic brake system under pressure for leaks. ● Inspect engine covers.
10.	DIAGNOSE	To identify cause/source of a malfunction.	● Determine corrective action for overheating in shock absorber.
11.	DISASSEMBLE	To reduce to basic components by temporary removal from primary assembly.	● Remove top deck and transmission shroud. ● Disconnect generator air duct.

TABLE 1 (CONTINUED)

	PROCEDURAL ACTION	DEFINITION	OPERATIONAL EXAMPLE
12.	ELEVATE	To raise up.	● Elevate main gun to "X" mils.
13.	FOCUS	To bring an image into view so it is clear and well-defined.	● Adjust brightness of reticle on infinity sight and align sight on target.
14.	INSTALL	To reconnect or attach to become part of a larger assembly.	● Replace firing pin assembly.
15.	JOIN	To link two or more component parts.	● When link is installed join track.
16.	LOOSEN	To release pressure or tension.	● Loosen track tension before breaking track.
17.	LOWER	To drop from a high to a lower position	● Lower breech block to floor of turret using chain hoist.
18.	LUBRICATE	To oil, grease, or coat with a friction-reducing material.	● Lubricate turret at stated intervals.
19.	MEASURE	To compare levels, outputs, clearances, performance against pre-set criteria.	● Measure clearance on servo band screw.
20.	PLUG	To close or seal.	● Plug open lines and ports (super-elevation actuator).
21.	REPLACE	To exchange one piece for another.	● Replace faulty wire and check for continuity.
22.	SECURE	To attach one piece to another, or to attach a lifting device to a major component.	● Secure breech block with chain hoist.
23.	START UP	To activate from an inactive state.	● Start up engine and check for leaks.
24.	SWITCH	To control a flow of energy, material so it is complete, (or interrupted).	● Switch on electrical power and test for continuity. ● Ensure master switch is off.
25.	TORQUE	To apply turning force to fix a nut or collar firmly in place.	● Torque the nut to 60 foot pounds.

TABLE 2

DEFINITION OF BEHAVIORAL ELEMENTS

BEHAVIORAL ELEMENT	DEFINITION
LOCATION	To specify the spatial position of an object.
IDENTIFICATION	To name (or indicate) an object, symbol, or signal that has been indicated (or named).
RECALL	To state or use knowledge of specific facts, rules, or organization of information.
COMPARISON	To perceive two objects or signals and report a match or difference between them on the basis of specified features or characteristics.
CLASSIFICATION	To assign objects or signals to predetermined categories.
GENERATION*	To specify a set of specific faults that may be the cause of a malfunction.
SELECTION*	To choose a possible fault to investigate during the process of troubleshooting.
SKILLED PERFORMANCE	To initiate and complete a precise motor behavior or sequence of motor behaviors.

*Combined in subsequent paragraphs for ease of discussion.

RELATING PROCEDURAL ACTIONS TO BEHAVIORAL ELEMENTS

A key step in developing the training guidelines consisted of categorizing sets of procedural actions by their relationships to the behavioral elements involved in performing maintenance. Relating actions to behavioral elements helped check on the comprehensiveness of the set of behavioral elements defined above and also served as a preliminary guide to the behavioral elements that should be incorporated into the final maintenance OJT model.

A comparison of the definitions for each behavioral task element and procedural actions resulted in the identification of five sets of procedural actions related to an associated group of behavioral task elements (see Table 3).

An examination of Table 3 will show that each one of the majority of the procedural actions (numbers 1-10) can be accomplished with only three behavioral

TABLE 3

SUMMARY OF BEHAVIORAL ELEMENT SETS AND
RELATED MAINTENANCE TASK PERFORMANCE STEPS

BEHAVIORAL ELEMENT GROUPS	PROCEDURAL ACTIONS
Location Identification Skilled Performance	1. Attach 2. Block-up 3. Break 4. Elevate 5. Join 6. Loosen 7. Lower 8. Lubricate 9. Plug 10. Secure
Location Identification Recall Skilled Performance	11. Assemble 12. Disassemble 13. Install 14. Replace 15. Start-up
Location Identification Recall Comparison Skilled Performance	16. Adjust 17. Bleed 18. Charge 19. Clear 20. Focus 21. Measure 22. Position 23. Torque
Location Identification Classification	24. Check
Location Identification Classification Generation Selection	25. Diagnose

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elements; procedural actions 11-15 require four behavioral elements; while procedural actions 16-23 require the exercise of five different behavioral elements for maintenance task completion.

The most difficult maintenance task—defined as procedural action #25—"diagnose"—also requires five types of behavioral activity.

Note also that 23 of the 25 procedural steps require locating, identifying, and skilled performance behavioral elements. Tasks and procedures that require recalling, comparing, classifying, generating, and selecting behavioral elements are those with unique characteristics and complexity, e.g., #25, "diagnose."

The significance of the relationships shows in Table 3 may be emphasized by an example of torquing a nut (procedural action #23) to a specified level of tightness. The elements of behavior related to this maintenance action are location, identification, recall, comparison, and skilled performance.

In operational terms, the mechanic must **locate** the nut to be tightened (find its general spatial position on the engine), he must then **identify** the particular nut (distinguish it from all the other nuts in the area—e.g., top of a cylinder block), he must **recall** the foot pounds pressure required (retrieve the information from his memory or remember in which TM it is stored), he then reads the scale of foot pounds on the wrench (**comparison**) to find out how much pressure is needed, he provides **skilled performance** to make the adjustment (uses motor skills to avoid overtightening beyond the setting needed).

A PRELIMINARY PROCEDURAL MODEL

The investigation of maintenance tasks related to behavioral elements of task performance has been based upon different levels of activities (i.e., major job task, performance step, and behavioral element) related to each activity category. General descriptors of maintenance tasks also used in the performance steps for each task, such as repair, replace, and troubleshoot, were then categorized by specific procedural action descriptors such as assemble, drain, torque, unscrew, etc. Each procedural action was subsequently assigned to one of the five subsets or

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groups of the behavioral elements previously described in Table 2. This assignment led to development of logical sequences, or combinations, of those behavioral elements needed to complete a maintenance task. Figure 2 graphically portrays the sequence in which each subset or group of elements would be used. Since the behavioral elements listed in the figure are described in directive terms, the "bullets" in each element block will clarify the application of each element. The behavioral sequences shown in Figure 2 represent a preliminary step toward development of an OJT model. The training guidelines discussed in Part II following will be related in the model to the various combinations of behavioral elements illustrated in Figure 2.

OJT, by its very nature, must be done in the sequence mandated by the nature of the repair task. Repair tasks requiring mechanic behavioral elements such as those shown in sequence 1, Figure 2, should be trained by first applying appropriate training guidelines to teach **locating**, then by applying relevant guidelines to teach **identifying**, before applying the training guidelines to teach **performing** (the necessary motor skills).

But the sequences shown in Figure 2 represent only one factor that should be incorporated into an OJT Model. Other factors needed to complete the model include the transition of the training guidelines into practical terms for application to OJT on the shop floor, and the validation of the relationship existing between behavioral elements and maintenance procedural actions.

Part III of this report presents summaries of the research findings that led to development of the training guidelines. The operational examples used in the discussion illustrate the direction in which the transition must be made from identification of the training guidelines to operational field use. Implementation of an OJT model will incorporate training guidelines for the user.
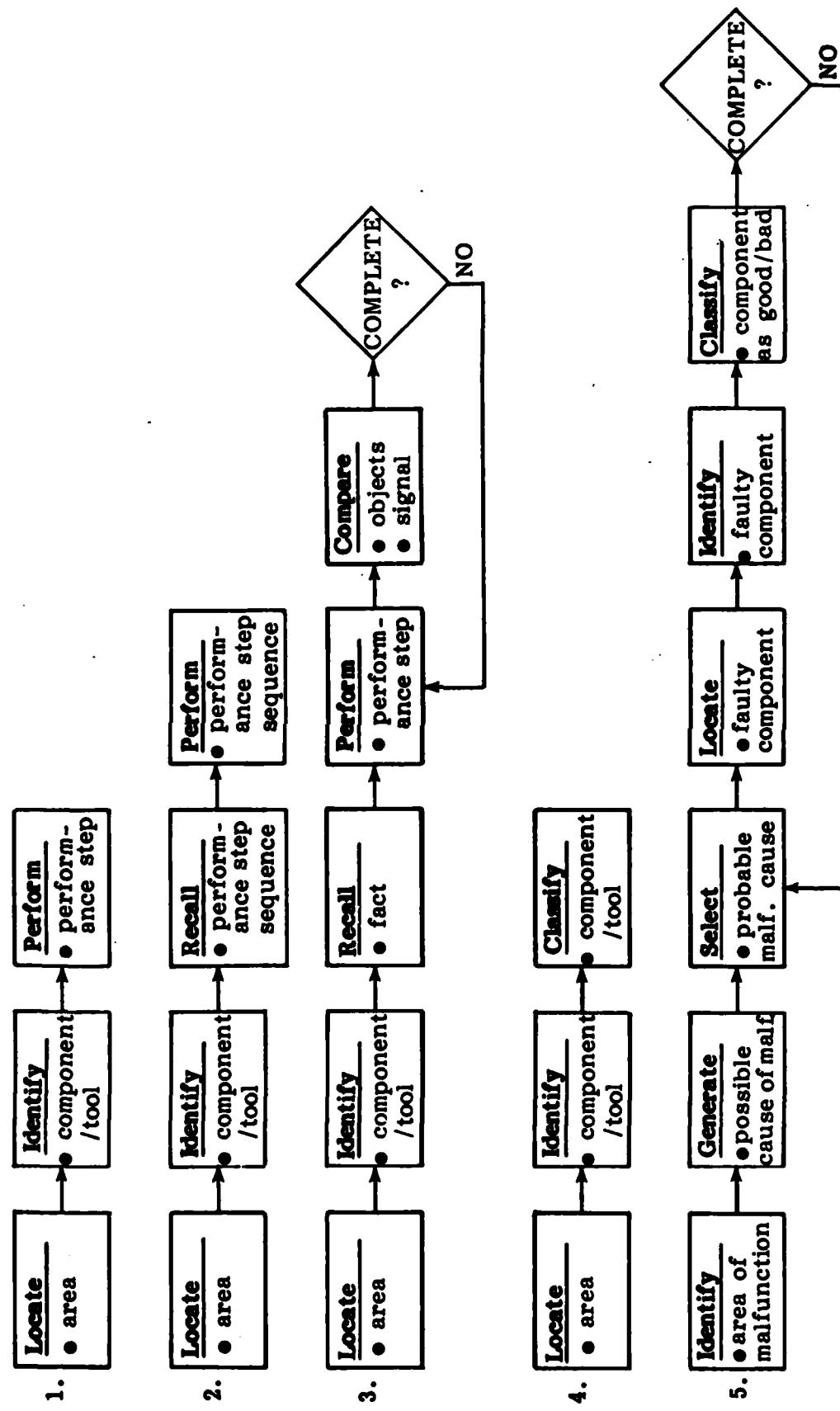
Figure 2. Sequence of application of behavioral elements in five logically arranged groups.

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PART II: TRAINING GUIDELINES LINKED TO BEHAVIORAL ELEMENTS

Part I presented the steps by which behavioral elements inherent in maintenance task performance were developed and related to the operational actions involved. The end product of that phase of the work was a set of procedural actions and a set of sequences for best use of the behavioral elements.

Part II defines the training guidelines, discusses their origin, and relates them to each behavioral element.

The identification of the training guidelines resulted from review of relevant sources identified during an extensive literature search. The sources included the Defense Technical Information Center (DTIC), the Educational Resources Information Center (ERIC), Psychological Abstracts, and the maintenance documents library at Anacapa Sciences, Inc.

One notable effort to identify training guidelines based on a taxonomy of maintenance task components, similar to the present set of behavioral elements, has been reported by Aagard and Braby (1976), who undertook a similar review. They compiled a composite set of guidelines based on information from texts in learning and education. Our approach, i.e., relating training guidelines developed from research results to required behavioral elements, avoids the difficulties inherent in relying solely upon specialized texts in learning and education.

But difficulties of another kind suggest possible limitations to the generality of the guidelines provided in this part. For example, the research cited in support of the guidelines was usually conducted in university laboratory environments using students as subjects rather than military personnel. However, no better source of information seems to exist concerning factors that influence training of basic skills of the type required by maintenance mechanics.

The remainder of this section is organized into seven subsections. Each behavioral element is discussed separately in these subsections, with the exception of "generation" and "selection" which are combined. Each subsection is presented in a standard format whereby behavioral elements are first defined, followed by the training guidelines appropriate to each behavioral element. However, note

carefully that the training guidelines in each group are not presented in sequential or ranked order. When the OJT model is developed, the guidelines will be incorporated in a systematic way and will be assessed later in the actual organizational-level maintenance environment.

LOCATION OF OBJECTS

Location refers to the requirement in maintenance to specify the spatial position of an object. How mechanics locate components or tools is a behavioral element prerequisite to performance of most maintenance tasks. Maintenance personnel will be more efficient if they can readily locate components to be maintained and tools to perform maintenance. Efficiency of task performance is enhanced by locating components and tools with minimal aid from reference material or supervisors. (Knowledge of reference material is subsumed in the discussion of recall. This section only considers factors that influence memory for spatial position.)

Guidelines for Location Training

The following four guidelines are based upon research findings related to location training. The guidelines summarize, from the research literature, how to better remember the location of objects in the organizational maintenance environment.

1. Present the location of unfamiliar objects in a context of familiar spatial arrangements of objects.

2. Present a simplified, schematic representation of complex spatial relationships.

3. Present complex systems (or illustrations) in sub-component or sub-system terms and impress the usefulness of this strategy on trainees.

4. Instruct trainees to construct mental images of objects as they are located relative to a unique, recognizable point.

IDENTIFICATION OF OBJECTS, SYMBOLS, OR SIGNALS

Identification refers to either of two needs in maintenance: to name an object, symbol, or signal that has been indicated (i.e., item – name); to indicate an object, symbol or signal that has been given a name (i.e., name – item). These two activities are complementary because both require knowledge of an object-name relationship. Accurate identification of components is a critical element in the majority of maintenance tasks. Discussion about equipment between maintenance personnel is made easier by access to a common vocabulary of identifying terms. Personnel who are highly skilled in identifying equipment components will also be efficient in ordering replacement parts. Identification is an important character- istic when following specific procedures. If a procedure requires an action that must be performed upon a named part, obviously the task cannot be performed until the part has been identified.

Guidelines for Identification Training

The following seven guidelines are based upon research findings related to identification training. The guidelines specify training practices that will facili- tate identification training.

1. Require the trainee to differentiate among similar items by unique characteristics of each item.

2. Require the trainee to attempt to recall one member of each item- name pair being learned.

3. Randomize the serial order in which pairs are presented.

4. Conduct both item-name and name-item training.

5. Present the most difficult pairs of item-names and name-items frequently.

6. Present the objects in all visual perspectives that could be encountered in the operational setting.

7. Continue training after identification is first mastered.

RECALL OF FACTS, TASK SEQUENCES, RULES, AND ORGANIZATION OF INFORMATION

Recall refers to the continued need in maintenance to use knowledge of specific facts, task sequences, rules, or organization of information. Recall of a specific fact, such as tolerance or clearances during alignment, is an efficient strategy in the performance of many common tasks. By correctly recalling often-used facts of this type, time spent referring to manuals can be more profitably spent "turning wrenches." Specific procedures for assembly can often be accomplished more easily if a simple set of sequential steps can be recalled, rather than having to refer to manuals. Recall of rules (sequences), such as the proper procedure for assembly of a major component, is valuable. Finally, recalling how technical information is organized in a publication is a recurring maintenance need. For example, recalling how a maintenance manual is arranged will facilitate one's search for a specific reference. General techniques for facilitating recall have been summarized below.

Guidelines for Facilitating Recall

The following six guidelines are based upon research findings related to the facilitation of recall. The guidelines summarize what can be done to improve a trainee's recall of specific facts, task sequences, rules, and organization of information.

1. Introduce accurately the material to be recalled.

2. Organize the material for recall in an efficient and methodical way.

3. Vary the ways of presenting the material to reinforce strategies of recalling.

4. Present reinforcing details related to the material that is to be recalled.

5. Instruct trainees to construct mental images of component item characteristics.

6. Discuss or present the cues for recall that will be available in the operational setting.

COMPARISON OF OBJECTS OR SIGNALS

Comparison refers to the need in maintenance of perceiving two objects or signals and reporting a match, or difference between them, on the basis of specified features or characteristics. The features or characteristics used in comparisons are usually specified as one or more physical attributes of the objects or signals, such as size, length, color, weight, intensity, frequency, viscosity, etc. The comparison of two objects or signals is a fundamental element of many maintenance tasks performed at the organizational level. Comparison is the activity whereby a calibrated instrument is used to measure a component. For example, measurement of the clearance of a fan within its housing requires the comparison of the thickness of a feeler gauge strip with the space between the fan blades and the housing. Some comparisons, of course, do not involve a calibrated instrument. In these cases, the comparison may be part of identification of a malfunction indicated by the difference in appearance between a shiny new component and a burnt, worn, and used component.

Guidelines for Comparison Training

The following six guidelines are based upon research findings related to comparison training. These guidelines specify practices that will facilitate comparison training.

1. Ensure that trainees are generally familiar with the objects or signals that are to be compared.

2. Accurately specify and describe the features or characteristics to be used in comparing the objects or signals.

3. Specify the degree of tolerance required for accurate comparison.

4. Have trainees practice distinguishing between different objects or signals.

5. Progress from easy to difficult comparisons during training.

6. Present the range of objects or signals that will be encountered in the operational setting.

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CLASSIFICATION OF OBJECTS OR SIGNALS

Classification refers to that maintenance activity whereby a mechanic must assign objects or signals to predetermined categories. Categories are composed of sets of objects or signals that are similar to one another. Classification plays an important role in maintenance. For example, if a mechanic is required to inspect transmissions and replace them when faulty, he must be able to classify the transmissions as either faulty or functional. The mechanic who is skillful in diagnosing transmission faults can classify transmissions on the basis of specific performance characteristics. The two categories of transmissions sound different and may look different to the mechanic who has learned to classify them. The person who can classify transmissions as faulty or functional has therefore learned to identify the relevant features of transmissions. Note that classification is a skill learned by exposure to training and shop practice, such as those shown below.

Guidelines for Classification Training

The following eight guidelines are derived from research findings related to classification training. These guidelines specify training techniques that will improve classification ability.

1. Describe accurately the categories to be used in classification.

2. Describe important features and rules used in classification.

3. Require the trainees to describe the categories and distinguishing features in their own terms, wherever possible.

4. Have trainees compare the objects or signals to be classified with one another before, and during, classification practice.

5. Progress from gross to subtle classifications during training.

6. Present the range of objects or signals encountered in the operational setting.

7. Provide knowledge of results to the trainee after each classification.

8. Continue training after the task is initially mastered by the trainee.

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GENERATION AND SELECTION OF ALTERNATIVES

Generation and selection of alternatives represent the primary behavioral elements in maintenance tasks requiring decision-making or fault-finding. (Because of the close interrelationship between these two task elements, both are discussed here.)

Within the context of decision making and fault finding in the organizational maintenance environment, **generation refers to the activity of specifying a set of alternatives that should be considered during the decision-making process.** The most common example of generation involves developing preliminary hypotheses about the cause of an equipment malfunction. Troubleshooting checklists and routines, of course, are available for all troubleshooting tasks authorized for the organizational level of maintenance. But generating a set of possible causes of a malfunction is still a valuable skill for organizational maintenance mechanics. Fuller, Rugge, and Harris (1981) have reported that maintenance mechanics avoid reference to the troubleshooting aids in technical manuals. The present project has one objective, among others, of improving maintenance practices by raising the skill levels of mechanics through OJT. Improving the ability of trainees to hypothesize on the possible causes of equipment malfunction is consistent with this objective.

Selection refers to the activity of choosing a preferred item from a set of alternatives. Selection is an activity, then, most commonly required in the organizational maintenance environment when one of a set of possible causes of a malfunction must be investigated. Skilled selection consists of selecting the possible cause that is most cost-effective to investigate at a given time. Cost-effectiveness is determined by the probability that a possible cause is the actual cause of a malfunction, and the amount of time and effort required to assess whether or not a possible cause is the actual cause of a malfunction. When fault-finding aids are used by the mechanic, selections from alternatives are still required for the effective use of these lists and schematic routines. When fault-finding aids are not used, the amount of skill employed in selection of a probable cause of a malfunction is critical to determining the efficiency of a mechanic's troubleshooting techniques.

Guidelines for Generation and Selection Training

The following nine guidelines are based upon findings in reseach related to either generation or selection training. These guidelines specify practices that will facilitate generation and selection training.

1. Have trainees defer premature evaluation of possible causes during initial stages of generation training.

2. Have trainees consider each symptom of a malfunction separately during initial stages of generation training.

3. Encourage students to probe the reasons for equipment malfunctions.

4. Require trainees to state their rationale for causes selected for investigation during training.

5. Have trainees evaluate their own and other's malfunction "cause" selections during training.

6. Teach specific troubleshooting techniques, such as the Half-Split technique,* when applicable.

7. Present malfunctions most likely to occur in field conditions during initial stages of training.

8. Progress from easy to difficult troubleshooting problems during training.

9. Continue each session of training to the point of problem solution (i.e., isolation of the actual fault).

SKILLED PERFORMANCE

Skilled performance in maintenance involves the initiation and completion of a precise motor behavior, or sequence of motor behaviors. Skilled performance involving learned motor skills represents a major portion of the activities that accomplish repair and upkeep of equipment. Adjustment and alignment tasks rely upon specific skill learning before precise motor behavior can be applied.

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*Defined in Part III.

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Maintenance personnel must often learn to attend to specific perceptual information as a basis for making precisely controlled movements while performing alignment tasks. For example, torquing a locknut while holding an adjusting nut requires attention to the pound feet reading of a torque wrench and the resistance of the locknut. In other tasks, learning the conduct of less precise actions is often required in the skilled performance of maintenance. For example, removal and replacement of components in a standard order often requires learning sequences of less precise motor behaviors.

Guidelines for Skilled Performance Training

The following five guidelines are based on research findings in skilled performance training. These guidelines specify practices that facilitate learning during skilled performance training.

1. Demonstrate the task prior to performance practice.

2. Provide accurate and complete feedback during and after performance practice.

3. Distribute practice in blocks of several repetitions of a task.

4. Practice only one task at a time; avoid practice of similar or competing tasks.

5. Continue practice after initial mastery of the task by the trainee.

PART III: SUMMARY OF RESEARCH FINDINGS

SUPPORTING TRAINING GUIDELINES

This part summarizes the research findings (and sources) which support the training guidelines listed in the preceding section. In addition to lending support to the guidelines, these findings are useful for suggesting ways in which training guidelines may be implemented since operational examples are used to clarify points in the discussion.

Part III is organized into seven subsections. Each behavioral element is discussed separately in these subsections, with the exception of "generation" and "selection" which are discussed together. Within each subsection, the research areas related to each behavioral element are specified, followed by a discussion of the research related to the appropriate training guideline for the behavioral element.

RESEARCH FINDINGS RELATED TO LOCATION OF OBJECTS

Those factors which have been found to influence people's ability to remember the location of objects are supported here. Studies investigating memory for the location of objects arranged in different configurations and presented briefly, comprehension of spatial information presented in different formats, and the process of map reading have identified the following factors which influence memory for the location of objects:

- Location of unfamiliar objects in familiar arrangements,
- Schematic representation of object location,
- Presentation of spatial information in segments, and
- Imagery of object location.

Each is summarized below.

Location of Unfamiliar Objects in Familiar Arrangements

A framework of familiar spatial arrangements facilitates memory for the location of individual objects within such arrangements. Studies by Goldin (1978), and Mandler and Parker (1976) represent work that has investigated memory for

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the position of common objects in pictures, and the position of pieces in strategic games, such as chess and "go." The most common finding here is that familiar arrangements of objects can be better remembered than less familiar arrangements. Mandler and Parker's work supports the notion that the unfamiliar location of an object is better remembered when presented within a more familiar arrangement.

This finding could be employed in training for locating engine components by taking advantage of a trainee's general knowledge of engine layout.

Schematic Representation of Object Location

Presentation of a simplified, schematic illustration of where objects are with respect to other objects facilitates comprehension of object location (e.g., Bartram, 1980). Bartram demonstrated that schematic representations of complex spatial arrangements facilitates location comprehension, rather than location memory. However, other research has demonstrated that memory for object location is facilitated when configurations are presented in more comprehensible formats (i.e., Goldin, 1978). Bartram's work demonstrates the superiority of schematic illustrations over more detailed illustrations or lists, in learning where objects are.

This finding could be employed in location training by presenting simplified schematics of subsystems or components of an engine when depicting the position of specific components, rather than showing actual photographs of equipment.

Presentation of Spatial Information in Segments

Partitioning large amounts of spatial information into subsets facilitates subsequent memory for location (e.g., Stasz & Thorndyke, 1980). This factor was identified in a study investigating the strategies employed by subjects attempting to remember information presented in maps. Stasz and Thorndyke noted that partitioning (or chunking) of spatial information could be accomplished using two distinct strategies. The first, conceptual partitioning, involves focusing upon specific characteristics of a map. The second, spatial partitioning, involves the study of limited areas or subsets of a larger illustration.

This second strategy could be implemented in location training in two ways. One would involve presentation of subsections of equipment during location training. Alternatively, trainees could be instructed to study illustrations by adopting a "divide and conquer" strategy in learning the location of equipment components.

Imagery of Object Location

Mental imagery in object location facilitates subsequent memory of where the object is located (e.g., Stasz & Thorndyke, 1980; Thorndyke & Stasz, 1980). This finding is based upon the same type of internal strategy used by subjects in experiments described previously. The work reported here is consistent with findings in recall of concrete words (c.f., Bower, 1972; Wollen, Weber, & Lowry, 1972).

Implementation of this finding would involve instructing trainees to develop mental images of tools or components in their correct location during study sessions.

RESEARCH FINDINGS RELATED TO IDENTIFICATION OF OBJECTS, SYMBOLS, OR SIGNALS

The following research findings came from experiments that studied the process of learning to pair words with other words or objects (i.e., paired-associate learning). Research involving object-word pairs is a technique used in predifferentiation training research. Most research in this area requires that after one item of a pair is presented, subjects are to attempt to anticipate, recall, or identify the other item. Research in paired-associate learning and pre-differentiation training have identified the following factors which influence the process of learning to identify objects, symbols, or signals:

- Initial training in discrimination,
- Practice in recall of object names,
- Presentation of pairs in varied sequences,
- Reversal of pair order,
- Practice with difficult items,
- Presentation of objects in different perspectives, and
- Continuation of practice.

Initial Training in Discrimination

Learning to discriminate between similar objects facilitates subsequent training in naming objects (e.g., Ellis & Shaffer, 1974; Kurtz, 1955). Training to identify objects, symbols, or signals which are not easily differentiated from one another can be done by practicing pairing the object with its name. The assumption is that trainees will learn to discriminate between objects, symbols, or signals during the course of training. A more efficient approach is to conduct training in comparing objects, symbols, or signals prior to training with names associated.

Practice in Recall of Object Names

Requiring the student to attempt to recall one member of a pair facilitates recalling both members of a pair (e.g., Battig & Brackett, 1961; Jacoby, 1978). Subject participation has traditionally been a cornerstone of name training. Most commonly, a student is shown one member of a pair, is then asked to name or indicate the other member, and is then told the correct answer. The study by Battig and Brackett demonstrates that this traditional approach may not necessarily be the most efficient. However, the conclusion is firm that active participation on the part of the trainee will greatly facilitate identification training.

Presentation of Pairs in Varied Sequences

Changing the serial position, or presentation order, of pairs within a list avoids unequal learning of object-name pairs (e.g., Glanzer & Cunitz, 1966; Madigan & McCabe, 1971; Martin & Saltz, 1963). The training guideline we have developed associated with varying the sequence of presentation, is based upon two separate research findings. First, when people study a list of items, the items at the beginning and end of the list are best remembered when memory is tested immediately; whereas delayed testing results in a substantially greater decrement in memory for items near the end of the list.

Second, changing the order of the items avoids this serial position effect without increasing the amount of practice required to master a set. But since it is often easier for an instructor to establish a list of items or present a set of objects without changing the order of presentation, the advantage of reinforcing learning by changing the order of presentation is often lost.

Reversal of Pair Order

Even after learning a pair in a specific order (i.e., object-name versus name-object), recalling the object's name is an easier task when one has just been shown the object, than when pointing to the object if one is only given its name (e.g., Ekstrand, 1966). This asymetry in paired-associate learning represents incomplete learning, which can be avoided if training alternates between name-object and object-name sequences.

Equipment disassembly aided by reference to a technical manual for removal of a named part requires identification of an object given a name (name-object training). Presumably the reverse holds whereby a mechanic could identify a part and would have to search through the task procedure in the equipment manual to find out what must be done with the part. By knowing the part's name (object-name training), the mechanic's search for related procedures listed in the equipment manual would be accomplished more efficiently.

Practice With Difficult Items

Repeating only those items that cannot be learned quickly is more efficient than repeating all items equally often (e.g., Atkinson & Paulson, 1972). It is unusual to find all items being learned equally quickly during identification training. Atkinson and Paulson have investigated a number of sophisticated methods of presentation to remedy this difference in the rate of acquisition. All of these methods share the characteristic of presenting the more difficult pairs most frequently. More frequent presentation of difficult pairs will lead to the trainee's learning the entire set in fewer trials than if all pairs are presented an equal number of times.

Presentation of Objects in Different Perspectives

Identification training that involves object-name training will result in better subsequent performance if the object is presented in all visual perspectives that could be seen in the operational setting (e.g., Dukes & Bevan, 1967).

For example, when assembling an engine, parts may appear different when laid out on a tray for assembly than when they are installed in a major subsystem of the engine. Being able to identify a part in both situations will facilitate maintenance performance. Thus, it would be helpful if object-name training included presentation of the object in perspectives expected in operational conditions.

Continuation of Practice

Subsequent identification performance will be enhanced if training continues beyond the point at which identification training is first mastered (e.g., Underwood, 1964). Underwood's study is only one of a large number demonstrating that continued training leads to better memory for name identification. It is especially important to maintain continuous identification training in those cases where use of the object name is infrequent in the operational setting.

RESEARCH FINDINGS RELATED TO RECALL

The area of psychological research focused on factors that influence recall is commonly referred to as verbal learning and memory research. We have noted two factors that influence verbal learning and memory: how information is originally presented to the person who must later recall that information; and what instructions are given to the learner on the best strategy to use for the recall of information.

Research in verbal learning and memory has identified these factors which facilitate recall of facts, task sequences, rules, and organization of information:

- Accurate introduction of material,
- Efficient and meaningful organization of material,
- Different interpretations of material,

- Details related to material,
- Imagery of concrete information, and
- Presentation of cues from the operational setting.

Accurate Introduction of Material

Accurate introduction of the material (to be learned) facilitates subsequent recall (e.g., Bransford & Johnson, 1972; Dooling & Lachman, 1971). The primary theme of the material should be summarized in an introduction, followed by the major points to be remembered, and the interrelationship noted between the different areas of information. An effective introduction may involve a pictorial explanation which can sometimes be very effective for introducing verbal material and improving subsequent recall of the information (Bransford & Johnson, 1972).

Efficient and Meaningful Organization of Material

Efficient and meaningful organization of verbal material facilitates subsequent recall (e.g., Bower, Clark, Winzenz & Lesgold, 1969; Britton, Westbrook, & Holdredge, 1978; Rosenberg, 1969). Effective organization of material requires attention to several aspects unique to verbal material, i.e., information within sentences is better remembered when common, simple words are used; material presented in passages composed of grammatically simple sentences and common words facilitates subsequent recall; and material that has an explicit and recognizable organization enhances the ability of students to recall the material. The Bower et al. report demonstrates the value of organizing verbal material in a hierarchical arrangement whereby key terms are highlighted for use to aid recall by trainees.

Different Interpretations of Material

Presenting material in several similar ways facilitates subsequent recall (e.g., Gartman & Johnson, 1972; Madigan, 1969; Thios, 1972). Most information that must be remembered can be thought of and applied in more than one way. For example, general rules of troubleshooting can be applied for diagnosing faults in a brake or ignition system. Research indicates that presentation of the techniques

applied to both applications will facilitate a trainee's retention of the (trouble-shooting) procedures. But note that the presentation of material in different contexts can only facilitate recall if the trainee thinks about the material in several ways. Madigan and Thios suggest that instructing people to think about verbal information in several similar ways should also facilitate subsequent recall.

Details Related to Material

Presenting details of verbal material facilitates subsequent recall (e.g., Battig & Einstein, 1977; Stein, Morris, & Bransford, 1978). It is important to give detailed descriptions and explanations of material. However, as the research demonstrates, elaboration is only effective if the additional information is relevant to the material that must be recalled.

For example, recall of the organization of a technical manual is more probable if the details under each major section are discussed. However, discussion of what is not included in each major section of a manual may interfere with subsequent recall of the organization. In fact, Stein et al. suggest that presentation of such irrelevant information will act as a barrier to subsequent recall. Battig and Einstein (1977) suggest that additional information need not always be presented by the instructor. Providing instructions to trainees to think about material details have also been shown to facilitate subsequent recall.

Imagery of Concrete Information

Memory for concrete information (i.e., information related to specific hardware items) is facilitated by instructing people to construct mental images that include the concrete items (e.g., Bower, 1972; Wollen, Weber, & Lowry, 1972). Use of imagery has been found to be a very effective technique for remembering concrete sets of information. Common, rather than bizarre, images are the most beneficial in facilitating recall.

Within the maintenance environment, this technique could be quite useful for recalling lists of tools or parts. By instructing trainees to construct mental images of the tools or parts in their common spatial positions, subsequent recall of the lists could be enhanced.

RESEARCH FINDINGS RELATED TO COMPARISON (DISCRIMINATION)

Research has demonstrated that accuracy in comparing objects or signals with a known standard or with one another can improve with training. These experiments are commonly referred to as discrimination learning experiments. This research has investigated the factors that influence the ability to learn how to respond to differences between two objects or signals. Much of the literature in discrimination learning is based upon research with animals, which has limited application to maintenance training. The factors influencing discrimination learning have not been widely researched in laboratories employing human subjects. However, some experiments have investigated factors which relate to the process of training individuals to compare objects or signals on the basis of specific features or characteristics. Useful factors of this type relate to:

- Initial familiarization with materials,
- Description of important features and characteristics,
- Specification of degree of tolerance in comparison,
- Practice comparing different objects or signals,
- Transition from easy to difficult comparisons, and
- Presentation of examples from the operational setting.

Initial Familiarization With Materials

Initial familiarity with the objects or signals to be compared facilitates subsequent training in the comparison procedures (e.g., Attneave, 1957; Bjorkman & Ottander, 1959). Familiarity is defined as having some previous experience with the objects or signals being compared. The experiment by Attneave investigated the effect of familiarity on comparison training using one single, typical object; whereas Bjorkman and Ottander investigated the effect of familiarity in making comparisons in a setting less structured than that used in structured on-the-job training. These two experiments suggest the importance of investigating a trainee's familiarity with the signals or objects to be compared prior to structured comparison training. These experiments also suggest that a period of familiarization should be incorporated into an initial phase of such training.

Description of Important Features and Characteristics

Accurate specification and description of the features or characteristics to be compared facilitates comparison training (e.g., Bornstein, 1976; De Rivera, 1959; Saltz, 1963). In many cases, accurate specification of the features or characteristics to be compared will be sufficient to ensure that correct comparisons will be made.

For example, the trainee who is familiar with the use of a feeler gauge will already have tactile knowledge of the degree of resistance met when the metal strip passes between two points at the correct setting. In other cases, specification and description of the features or characteristics will only represent an initial stage of training which must be followed by more sophisticated training in the use of test or measuring equipment.

Specification of Degree of Tolerance in Comparison

Specifying the degree of tolerance that can be allowed in comparisons facilitates comparison training (e.g., De Rivera, 1959; Ellis, Bessemer, & Devine, 1962). The degree of tolerance that can be allowed in making comparisons should always be made explicit. Since comparisons may be ultimately based upon mechanics' judgment, the correct criteria for such judgments must be specified.

In some cases, tolerance can be adequately specified via physically scaled dimensions, such as foot pounds or torque. In other cases, tolerance must be learned through experience, for example, the feel of a screwdriver when a screw is sufficiently tight to hold, without it being so tight that later removal is difficult--or even impossible.

Practice Comparing Different Objects or Signals

Practice in making comparisons between objects or signals that differ from one another is essential to comparison training (e.g., Englund & Lundberg, 1963). Experiments in discrimination training suggest that it is familiarization with differences, rather than the signals or objects themselves, that is critical to improvement in the performance of comparisons. Accurate comparison is often a prerequisite to identification training.

For example, a useful skill for mechanics is to be able to identify specific socket sizes by sight whereby they visually compare the relative size of the sockets. Training using this principle would involve showing the set of sockets to new mechanic-trainees so they could learn what the differences in size look like, rather than presenting each socket separately.

Transition From Easy to Difficult Comparisons

Gradual transition from easy to difficult comparisons facilitates discrimination training (e.g., Baker & Osgood, 1954). This finding is limited to research focused on investigating comparisons between different objects or signals. By having trainees initially make easy comparisons, familiarization with the characteristics or features to be compared is more readily accomplished. Subsequent training with more difficult comparisons then helps the trainee become familiar with the finer discriminations required by a comparison task.

Presentation of Examples From Operational Setting

Training encompassing the total range of objects or signals that will be encountered in the operational setting will facilitate subsequent accuracy of comparisons (e.g., Heimer & Tatz, 1966). They suggest some learning always occurs when a limited set of objects or signals are compared during training. However, the accuracy of subsequent comparisons is greatly enhanced if training includes the entire range of objects or signals that will be encountered in the operational setting.

If the sockets (described in a previous example) range in size from 1/4" to 1-1/2" in 1/16" increments, this range should be included in comparison training. Note that although the difference between 1/4" and 5/16" sockets is similar to the difference between 1-3/16" and 1-1/4" sockets, there are dissimilarities in the cues used in making the two comparisons.

RESEARCH FINDINGS RELATED TO CLASSIFICATION (CATEGORIZATION)

Research in concept identification focuses on factors that influence learning to identify features and rules of different categories. Experiments in form discrimination learning study the process of learning to distinguish similar forms from one another. Research that investigates the learning process called schema learning studies the process whereby the general characteristics of objects or signals that define category membership are recognized. These areas of research have demonstrated that the following factors facilitate learning to classify objects or signals:

- Description of categories,
- Description of important features and rules,
- Trainee participation in description,
- Initial comparison training,
- Transition from easy to difficult classifications,
- Presentation of examples from operational settings,
- Accurate feedback during training, and
- Continuation of practice.

Description of Categories

Accurate description of the categories used in classification facilitates such training; whereas inaccurate or irrelevant descriptions impede training (e.g., Daniel, 1972; Pfafflin, 1960).

Description of Important Features and Rules

Accurate description, illustration, or presentation of important features and rules used in classification facilitates training; whereas inaccurate information or emphasis of unimportant features impedes training (e.g., Bornstein, 1976; Haygood & Bourne, 1965; Homa & Coury, 1977; Hull, 1920). "Important features" refers to those characteristics of objects or signals that distinguish one category of objects or signals from others.

For example, important features of a faulty transmission may be a grinding noise, oil leakage at a particular location, or slippage when the transmission is engaged. Classification training will be more effective if the trainee is shown each of these conditions.

In some cases, the presence of a feature will indicate category membership. In others, the absence of features will govern category membership. For example, slippage of a transmission may indicate a need for repair; whereas oil leakage may indicate a need for repair only when a grinding noise is also present. Trainee familiarity with these rules can, of course, be gained through experience, but an explicit statement of such rules in advance will reduce the time required to learn them.

Trainee Participation in Description

Trainee participation in describing the categories, features, and rules used in classification facilitates training (e.g., Ellis & Muller, 1964; J. Gibson & E. Gibson, 1955). Allowing a trainee to participate in the description of objects that must be classified has three advantages: first, it gets the trainee involved in actively seeking ways to distinguish objects from one another; second, by using their own descriptions, trainees will be able to relate the classification into those specific categories previously learned; and third, trainee suggestions may be useful for incorporation in future training.

Initial Comparison Training

Comparison of objects or signals with one another, both before and during training, facilitates classification training (e.g., Ranken & Evans, 1968; Smallwood & Arnoult, 1974). It would thus be helpful to have a set of the items to be classified available during training.

For example, training in classifying hydraulic drive belts as within, or outside of, wear limits would be enhanced if it included demonstration of a set of new and replaced belts. Trainees could be asked to rank worn belts according to to the probability that they would lead to a malfunction.

Transition From Easy to Difficult Classifications

Training that begins with easier classifications and progresses to more difficult classifications reduces the total amount of training required (e.g.,

Bregman & Charness, 1970; Bruner & Potter, 1964; Edmonds & Mueller, 1970; Hull, 1920). Classifications become more difficult when they have a larger number of irrelevant cues, less distinctive or salient features, a larger number of relevant features, or have less similarity to the textbook examples used in classification training. When trainees have to classify several different types of equipment, classification is easier to teach by beginning with the equipment that is most easily classified.

When training in how to classify a potentially faulty transmission, one could start by comparing a new transmission with one that has had needed repairs deferred for a long period of time, before conducting subsequent training in classifications based upon more subtle cues.

Presentation of Examples From Operational Settings

Training people to classify all of the different types of objects or signals that must later be classified after training, results in more accurate post-training classification than training with a more limited range of objects or signals (e.g., Bregman & Charness, 1970; Posner & Keele, 1968). As previously noted, efficient learning of the classification of objects or signals requires exposure to the range of examples that may later be encountered.

For example, there may be a number of different causes for transmission oil leaks--one oil leak may only involve spillage from another component, another may require tightening bolts, and a third type may be caused by a broken seal in the transmisison. The trainee will not be able to make the necessary classification in all possible cases without adequate exposure to the range of causes during training.

Accurate Feedback During Training

Training that includes feedback (i.e., knowledge of results) after each classification facilitates learning (e.g., Bourne & Bunderson, 1963; Matthews, 1972; Smallwood & Arnoult, 1974). The research cited indicates that two conditions must be met if feedback is to be valuable in training. First, it must provide adequate information relevant to the degree of success in classifying objects into categories.

That is, a simple "right" or "wrong" may not prove useful in learning, whereas more descriptive feedback indicating specific features or rules will facilitate learning. Second, sufficient time between feedback and the resumption of training must be allowed, so the trainee may mentally reorganize the information he uses to make classification decisions. Time is an especially necessary factor if trainees have been classifying on the basis of an improper feature for a period and then, when the improper feature is discovered, have been given corrective feedback.

Continuation of Practice

Overlearning during training reinforces initial classification skills and their subsequent retention (e.g., Homa, Cross, Cornell, Goldman, & Schwartz, 1973; Ellis & Muller, 1964). Overlearning is accomplished by continuing training and practice after initial mastery of practice tasks. In teaching classification, it is important that continued classification training includes practice with more varied and difficult objects or signals.

RESEARCH FINDINGS RELATED TO GENERATION AND SELECTION OF ALTERNATIVES

Research results demonstrate that training can help subjects generate alternative solutions to problems and from these alternative solutions, select specific alternatives to investigate. Research concerned with instructional techniques for improving problem-solving skills contains many such inferences.

Three specific areas of research directly applicable to the requirements for generation and selection of alternatives in organizational maintenance problems are: research concerned with identifying techniques for improving the quantity and quality of alternative problem solutions generated; research concerned with identifying techniques for improving the efficiency whereby alternative problem solutions are assessed; and research concerned with improving the ability to solve troubleshooting-type problems. Much of the research in these areas is subjective and does not involve the experimental comparison of alternative training techniques. However, our review resulted in identification of the factors below that facilitate learning how to generate and select alternatives:

- Deferring judgment during generation,
- Consideration of symptoms during generation,
- Inquiry skill training,
- Trainee statement of rationales for selection,
- Trainee evaluation of selections,
- The use of specific techniques in generation and selection,
- Presentation of malfunctions resulting from common faults,
- Transition from easy to difficult problems, and
- Continuation of problem-solving from start to final solution.

Deferring Evaluation During Generation

Practicing a policy of deferring evaluation of alternatives during training in generation of hypotheses increases the number of alternatives generated (e.g., Olton & Crutchfield, 1978). The value of such a policy is often cited in publications describing productive strategies for problem solving. The value of this technique is that the constraints people impose upon their search for alternative solutions to specific problems are reduced. Of course, generating a greater quantity of alternatives does not necessarily lead to better quality of these alternatives. However, if trainees cannot generate a sufficient number of possible reasons (alternative causes) for equipment malfunction, deferring judgment on those they do generate could prove useful as a first step in teaching more skillful generation and decision-making techniques.

Consideration of Symptoms During Generation

Considering each symptom of a problem separately results in improved generation of alternative solutions (e.g., Olton & Crutchfield, 1978). This finding represents a technique of problem definition applicable to troubleshooting tasks. Most equipment malfunctions have numerous symptoms. Investigating each symptom separately reduces the likelihood of overlooking a possible fault. This research (cited above) incorporated a technique for choosing the most plausible alternatives from those generated. Since the experimental design of the work used both techniques, the results are confounded and difficult to assess.

Inquiry Skill Training

Asking questions about problems and receiving prompt and reasonable responses by instructors results in improvements in the quality of alternatives generated (e.g., Suchman, 1964). This finding represents a training technique designed by Suchman to refine students' skills in investigating a problem. In contrast to the first two techniques employed by Olton & Crutchfield, Suchman was primarily concerned with improving the quality, rather than quantity, of alternatives generated by his subjects.

Trainees' Statements of Rationales for Selection

Providing a stated rationale during training for selections results in improvements in the quality and efficiency of selection of alternatives (e.g., Gagné, 1962; Whimbey, 1979). This finding represents a technique that requires trainees to define the logic behind their selection of faults to investigate during troubleshooting. It also provides the instructor a way of assessing the current level of trainees' troubleshooting skills. The study by Gagné suggests that the additional training time required by this technique is offset by the later increases in speed and efficiency of troubleshooting exhibited by people trained in this way.

Trainee Evaluation of Selections

Practice in evaluating one's own and solutions of others to problems results in improvements in the selection of alternative solutions (e.g., Hyman, 1961; Whimbey, 1979). The implementation of the training technique represented by this finding is closely related to that discussed above.

For example, discussion about troubleshooting by the trainee affords himself and the instructor an opportunity to assess the logic used in the process of decision making. Additionally, these techniques require the trainee to consider alternatives on the basis of explicit criteria.

The Use of Specific Techniques in Generation and Selection

Instruction in specific techniques of generation and selection, such as the "Half-Split" technique, improves troubleshooting skills in cases where the techniques can be applied in the operational setting (e.g., Goldbeck, Bernstein, Hillix, & Marx, 1957). The "Half-Split" technique for troubleshooting describes a technique where equipment is progressively investigated in equally divided portions or subsections until the cause of the malfunction is found. Similar techniques are represented by the "GO, NO-GO" schematic troubleshooting routines provided in the equipment manuals.

Presentation of Malfunctions Resulting From Common Faults

Subjects tend to generate alternatives and select from alternatives on the basis of problems provided as examples to be learned during training (e.g., Neimark, 1967). The study cited here used a troubleshooting problem for investigating the influence of a subject's past experience with specific types of faults on later approaches to troubleshooting.

The finding suggests the importance of initiating troubleshooting training using examples of equipment malfunctions caused by common faults. If seldom-encountered faults are used as examples during the instruction of inexperienced trainees, trainees often will look for similar faults to investigate during later troubleshooting in the unit.

Transition From Easy to Difficult Problems

Improvement in generation and selection is facilitated by training that emphasizes a transition from easy to more difficult problems (e.g., Whimbey, 1979). The two most obvious ways to characterize the difficulty of a trouble-shooting task are on the basis of equipment complexity and on the number of possible causes for a specific malfunction. It follows that less complex equipment and/or malfunctions that do not involve a large number of possible causes should be employed as examples during early training in troubleshooting. However, it is also important that trainees receive practice during more advanced training on more complex equipment and malfunctions.

Sequence Training in Problem Solving to Solution

Improvement in generation and selection is facilitated by continuing each session of training to the point where the trainee actually solves the problem himself (e.g., Bendig, 1957; Taylor & Faust, 1952). This finding suggests that the basic elements of generation and selection should be taught in the context of a complete troubleshooting procedure. The results of the research cited reinforces the more general principle that informative feedback is essential to learning. By continuing each session of troubleshooting training to the point of locating the actual cause of a malfunction, trainees in effect will be providing immediate knowledge of results to themselves from the actions they take during the total troubleshooting sequence.

RESEARCH FINDINGS IN MOTOR SKILL IMPROVEMENT

Research in skilled performance has traditionally focused upon tasks and methods that lend themselves to improving motor skills. The results of such research may thus be adapted to provide specific guidelines for motor skill training.

Research in skill acquisition can be categorized by the three basic types of skilled tasks: single discrete tasks, sequences of discrete tasks, and pursuit/ tracking tasks. The first two are relevant to the motor skills needed to perform maintenance. Research on the motor skills needed to perform single discrete tasks and sequential tasks has identified the most important factors that help the process of learning such tasks. They are:

- Initial demonstration of a task,
- Presentation of accurate feedback,
- Distribution of practice,
- Training separate tasks, and
- Continuation of practice.

Initial Demonstration of Task

Demonstration of the task prior to practice in its performance facilitates improvement of motor skills (e.g., Richardson, 1967; Rimland, 1955). A demonstration is useful for both discrete and sequential tasks. Such demonstrations provide a model for specific movements as well as an example of a complete sequence of movements. The study by Rimland shows that demonstrations are most beneficial to learning when the pace of presentation is sufficiently slow, or repeated a sufficient number of times, to allow comprehension of all steps by the student prior to practice.

Presentation of Accurate Feedback

Accurate and complete feedback during task execution is critical to learning a motor skill (e.g., E. A. Bilodeau, 1954; Kincade, 1963). Feedback should optimize presentation of critical information during the early stages of learning when it is appropriate and necessary for the instructor to provide additional information to the trainee during task performance.

For example, if it is difficult to read a torque wrench gauge when tightening a locknut and holding an adjusting nut, the instructor could periodically read out the pound feet that were indicated. In later stages of learning, feedback should consist of only that available in the operational setting. During final training, the instructor should minimize the amount of additional feedback provided by him during task performance, since such feedback will not be available in the operational environment.

Accurate feedback providing complete knowledge of results after a task is completed should be provided consistently during early stages of training (e.g., E. A. Bilodeau & I. McD. Bilodeau, 1958; Leonard & Conrad, 1963; Lorge & Thorndike, 1935; Taylor & Noble, 1962). In contrast to feedback that must be ongoing during the performance of a task involving motor skills, delay between task completion and provision of overall feedback is not critical to the acquisition of discrete information. However, it is important in training to allow some time to elapse between provision of knowledge of results and the next practice trial. A short

delay at this time allows a trainee time to reconsider his performance in relation to feedback.

Distribution of Practice

Distribution of practice typically represents the most efficient schedule for training (e.g., E. A. Bilodeau, & I. McD. Bilodeau, 1958; Ammons, 1951). Distributing practice in blocks represents a trade-off between two opposing effects-- massed practice on skilled performance. Minimizing the interval between repetitions reduces the forgetting of critical information by the trainee. However, numerous repetitions of a task can lead to decrements in performance. The trade- off between these beneficial and adverse effects of repetition is commonly maximized by training in blocks of several repetitions of a task with rest periods between successive blocks.

Training Separate Tasks

Performance of tasks involving non-complementary, or competing, motor skills during early stages of training will result in performance degradation (e.g., Kantowitz, 1972). The study demonstrated that performance of similar but competing movements during early stages of learning will result in degradation of the motor skill being learned. In practical terms, trainees should practice each task prior to combining the steps into a more fluid and automatic sequence. For sequential tasks, learning a specifically ordered sequence of procedural steps will be impaired if the steps are being performed in various orders for other tasks.

Continuation of Practice

Continued practice in the performance of a skilled task after initial mastery ensures initial skill learning and subsequent retention (e.g., Adams & Dijkstra, 1966; Fleishman & Parker, 1962; Mengelkoch, Adams, & Gainer, 1958). Sequential tasks that must be performed often or in situations where job aids are impractical are especially good candidates for extended practice.

APPENDIX A

KEY LIST OF RESEARCH SOURCES REVIEWED
FOR TRAINING GUIDELINES

Aagard, J. A. & Braby, R. **Learning guidelines and algorithms for twelve types of training objectives** (TAEG Report No. 23). Orlando, FL: Training Analysis and Evaluation Group, NTEC, 1976.

Adams, J. A. **Learning and memory: An introduction.** Hometown, IL: Dorsey, 1980.

Adams, J. A., & Dijkstra, S. Short-term memory for motor responses. **Journal of Experimental Psychology,** 1966, 71, 314-381.

Ammons, R. B. Effects of distribution of practice on rotary pursuit 'hits.' **Journal of Experimental Psychology,** 1951, 41, 17-22.

Atkinson, R. C., & Paulson, J. A. An approach to the psychology of instruction. **Psychological Bulletin,** 1972, 78, 49-61.

Attneave, F. Transfer of experience with a class-schema to identification-learning of patterns and shapes. **Journal of Experimental Psychology,** 1957, 54, 81-88.

Baker, R. A., & Osgood, S. W. Discrimination transfer along a pitch continuum. **Journal of Experimental Psychology,** 1954, 48, 241-246.

Bartram, D. J. Comprehending spatial information: The relative efficiency of different methods of presenting information about bus routes. **Journal of Applied Psychology,** 1980, 65, 103-110.

Battig, W. F., & Brackett, H. R. Comparison of anticipation and recall methods in paired-associate learning. **Psychological Reports,** 1961, 9, 59-65.

Battig, W. F., & Einstein, G. O. Evidence that broader processing facilitates delayed retention. **Bulletin of the Psychonomic Society,** 1977, 10, 28-30.

Bendig, A. W. Practice effects in "Twenty Questions." **Journal of General Psychology,** 1957, 56, 261-268.

Bilodeau, E. A. Accuracy of response as a function of target width. **Journal of Experimental Psychology,** 1954, 47, 201-207.

Bilodeau, E. A., & Bilodeau, I. McD. Variation of temporal intervals among critical events in five studies of knowledge of results. **Journal of Experimental Psychology,** 1958, 55, 603-612.

Bjorkman, M., & Ottander, C. Improvement of discriminative ability by training. **Reports from the Psychology Laboratory, University of Stockholm,** 1959, No. 66.

Bornstein, M. H. Name codes and color memory. **American Journal of Psychology,** 1976, **89,** 269-279.

Bourne, L. E., & Bunderson, C. J. Effects of delay of informative feedback and length of postfeedback interval on concept identification. **Journal of Experimental Psychology,** 1963, **65,** 1-5.

Bourne, L. E., Ekstrand, B. R., & Dominowski, R. L. **The psychology of thinking.** Englewood Cliffs, NJ: Prentice-Hall, 1971.

Bower, G. H. Mental imagery and associative learning. In L. Gregg (Ed.), **Cognition in learning and memory.** New York: John Wiley, 1972.

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APPENDIX B

ANNOTATED LISTING OF SOURCES REVIEWED

Adams, J. A., & Dijkstra, S. Short-term memory for motor responses. **Journal of Experimental Psychology**, 1966, 71, 314-381.

This experiment demonstrated that high levels of initial practice result in superior acquisition and retention of motor skills over short delays. Blindfolded subjects were given 1, 6, or 15 practice repetitions of an arm displacement movement. Accuracy of the movement was then measured at either 5, 10, 15, 20, 50, 80, or 120 second delays. The two primary effects seen when retention was measured were: error in the movement decreased as a function of amount of practice, and the group given 15 practices maintained their superiority in performance for all delays.

Ammons, R. B. Effects of distribution of practice on rotary pursuit 'hits.' **Journal of Experimental Psychology**, 1951, 41, 17-22.

This experiment compared the effects of massed and distributed practice on the acquisition of skill in a rotary pursuit task. Accuracy was recorded as the number of 'hits' and the time on target. It was found that practice with a distributed practice schedule resulted in performance that was characterized by more frequent and longer 'hits.'

Atkinson, R. C., & Paulson, J. A. An approach to the psychology of instruction. **Psychological Bulletin**, 1972, 78, 49-61.

This article reported experimental tests of three models representing the incremental process of learning. A basic finding of this research was that models that are based upon incremental learning with different items being learned at different rates are useful in improving the efficiency of training. In a general sense, the results suggest that repetition of training should be selective rather than exhaustive by repeating items that are not yet learned, more often than items already mastered.

Attneave, F. Transfer of experience with a class-schema to identification-learning of patterns and shapes. **Journal of Experimental Psychology**, 1957, 54, 81-88.

This experiment demonstrated that familiarity with a representative sample of the type of object or signal to be compared facilitates subsequent comparison training. Subjects practiced drawing a single unfamiliar pattern during familiarization training. In the next phase of the experiment, subjects learned to pair a different word with each of ten variations of the original pattern. Learning was found to be superior for this group, as compared to a group that had not received familiarization training.

Baker, R. A., & Osgood, S. W.   Discrimination transfer along a pitch continuum. **Journal of Experimental Psychology,** 1954, **48,** 241-246.

This experiment demonstrated that it is important to progress gradually from easy-to-difficult comparisons during comparison training. Three groups of subjects were given equal amounts of corrected practice in comparing tones that differed only in pitch. One group was trained only with a difficult series of tones. A second group was trained on an easy series. A third group began training on an easy series and approached the more difficult test series in gradual steps. Only the group trained in gradual steps of difficulty improved in their ability to compare tones on the basis of pitch.

Bartram, D. J.   Comprehending spatial information: The relative efficiency of different methods of presenting information about bus routes. **Journal of Applied Psychology,** 1980, **65,** 103-110.

This experiment demonstrated that complex spatial information can be more readily comprehended and used in a task requiring identification and comparison when it is illustrated in a simplified, schematic format. Subjects were presented bus routes in one of four formats: (1) as a detailed road map, (2) as a schematic map, (3) as a sequential list of bus stops, and (4) as an alphabetical list of bus stops. Subjects were given pairs of location names and were required to select a possible sequence of bus routes to get from one to the other location. Solution times were faster for maps than for lists of bus stops, and faster for the schematic map than for the detailed road map.

Battig, W. F., & Brackett, H. R.   Comparison of anticipation and recall methods in paired-associate learning. **Psychological Reports,** 1961, 9, 59-65.

This experiment demonstrated that immediate knowledge of results in paired-associate learning is not critical. Battig and Brackett compared the usual sequence of object-name training involving immediate knowledge of results following each recall attempt by a subject, with a condition requiring recall that delayed knowledge of results until recall had been attempted for all set pairs. The authors found more rapid learning with their alternative recall method, although the evidence indicates that this advantage only holds under restricted conditions.

Battig, W. F., & Einstein, G. O.   Evidence that broader processing facilitates delayed retention. **Bulletin of the Psychonomic Society,** 1977, **10,** 28-30.

This experiment demonstrated that instructing people to think about material to be remembered in more varied ways facilitates delayed recall. Subjects were asked to rate each word from a list on one to three semantic dimensions. The dimensions were either highly related to one another (concreteness, imagery, and categorizability) or relatively unrelated to one another (concreteness, pleasantness,

and number of word features). Subsequent recall 48 hours later was better when more dimensions had been used in rating a word and when the dimensions were unrelated to one another.

Bendig, A. W. Practice effects in "Twenty Questions." **Journal of General Psychology**, 1957, **56**, 261-268.

This experiment was an example of lack of improvement in the problem-solving ability of subjects when training did not include presentation of the problem solution. Subjects practiced a modified version of the game of "Twenty Questions," where only five questions per game were allowed. No improvement in problem solution over three games was observed in this study.

Bilodeau, E. A. Accuracy of response as a function of target width. **Journal of Experimental Psychology**, 1954, **47**, 201-207.

This experiment demonstrated the importance of providing accurate feedback to subjects during skill training. Subjects were trained to position a lever to a predetermined point. All subjects were given an accuracy score after each practice movement. However, the feedback scores were transformed true scores by making them 0, 2, 4, 8, or 16 units closer to the goal score than they actually were. Thus, the 0 group was given optimally accurate feedback, and the 2, 4, 8, and 16 groups worked with successively broader targets. Results indicated that groups with narrower targets, or more feedback, learned the positioning task more rapidly than the groups with broader targets.

Bilodeau, E. A., & Bilodeau, I. McD. Variation of temporal intervals among critical events in five studies of knowledge of results. **Journal of Experimental Psychology**, 1958, **55**, 603-612.

This series of experiments compared the effects of delay of knowledge of results and delay between practice responses on the acquisition of a motor skill. The delay between a first response and feedback, as well as the delay between two responses ranged from seconds to minutes, hours, days, and weeks. It was found in the studies that as delay between practice responses increased, learning of the motor task decreased. The authors interpret the series of experiments as indicating that the amount of delay between practice responses was the primary determinant of skill acquisition.

Bjorkman, M., & Ottander, C. Improvement of discriminative ability by training. **Reports from the Psychology Laboratory, University of Stockholm**, 1959, No. 66.

This experiment demonstrated that ability to accurately compare weights can improve with practice in the absence of knowledge of results. Two subjects practiced lifting and comparing weights over a five-day period. The difference in actual weight of objects that was noticeable to the subjects was reduced by approximately half during this period, indicating an improvement in the accuracy of comparisons between objects. This improvement took place in the absence of any knowledge concerning the accuracy of comparisons during training. Thus, familiarity with stimuli of this type can facilitate comparison training.

Bornstein, M. H. Name codes and color memory. **American Journal of Psychology**, 1976, 89, 269-279.

This experiment demonstrated how inaccurate description can impair subsequent identification. Subjects were shown a color they considered to be half-way on the color spectrum between two colors, such as green and blue. Before showing the color to be rememberd, Bornstein said it was more like one color, for example "blue-like." When later asked to recognize the color, people made errors in the direction of the label. The results suggest that later comparisons or classifications based upon the identification of specific features or characteristics of stimuli could be impaired if an incorrect description is initially provided.

Bourne, L. E., & Bunderson, C. J. Effects of delay of informative feedback and length of postfeedback interval on concept identification. **Journal of Experimental Psychology**, 1963, 65, 1-5.

This study demonstrated that an increased delay after knowledge of results facilitates categorization learning. Delay between knowledge of results and the resumption of training in a concept identification study was tested at 1-, 5-, and 9-second intervals. It was found that the number of trials required to identify a concept decreased, indicating more rapid learning, as the delay after knowledge of results was increased. Additionally, facilitation of learning was more pronounced when the task was difficult (5 irrelevant dimensions) than when it was easy (1 irrelevant dimension). This finding is consistent with the hypothesis that the period after knowledge of results is provided is used by the subject to consider new information obtained from knowledge of results.

Bower, G. H. Mental imagery and associative learning. In L. Gregg (Ed.), **Cognition in learning and memory.** New York: John Wiley, 1972.

This experiment reported direct evidence for the effectiveness of mental imagery in facilitating memory for word pairs. Subjects were given one of two

types of instructions for studying a list of word pairs. Subjects in the mental imagery group were instructed to imagine the two nouns in each pair interacting in a mental picture. Other subjects were simply told to study the words for a later retention test. Subjects given standard instructions remembered only two-thirds as many words, when cued with one of the pair members, as the group given imagery instructions.

Bower, G. H., Clark, M., Winzenz, D., & Lesgold, A. Hierarchical retrieval schemes in recall of categorized word lists. Journal of Verbal Learning and Verbal Behavior, 1969, 8, 323-343.

This experiment demonstrated that presenting verbal material in a meaningful, structured order facilitates later recall. Two groups of subjects were presented the same 112 words for four separate study-test trials. Half of the subjects were presented the words in meaningful hierarchical arrangements; whereas the other half were presented the words in meaningless hierarchical arrangements. Subjects who had been presented meaningfully organized materials recalled approximately three times as many words as the other subjects. Additionally, all of the subjects who had been presented the meaningfully organized material recalled all of the 112 words by the third trial.

Bransford, J. D., & Johnson, M. K. Contextual prerequisites for understanding: Some investigations of comprehension and recall. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 717-726.

This experiment demonstrated that pictures can be useful for presenting a preview of written information, resulting in better comprehension and recall. Two groups of subjects read a passage after seeing one of two pictures. Both pictures included the same objects. However, the thematic picture best represented the events of the passage. Subjects who were presented the thematic picture first recalled more of the passage than subjects who were presented a non-thematic picture.

Bregman, A. S., & Charness, N. "Schema plus transformations" in visual pattern recognition. Paper presented at Eastern Psychological Association, Atlantic City, New Jersey, April 1970.

This experiment demonstrated the interrelationship between level of learning and value of training with numerous examples of items from different categories. Subjects were trained to classify shapes that systematically varied in their similarity to an original prototype shape. Two factors of training were the number of training trials and average similarity (geometric distance) between training shapes and the prototype shapes. The authors reported that with minimum training, subjects could classify shapes with strong similarity to the prototype better than subjects who had to classify shapes dissimilar to the prototype. But, with intensive training in the whole range of shapes, classification was better.

Britton, B. K., Westbook, R. D., & Holdredge, T. S. Reading and cognitive capacity usage: Effects of text difficulty. Journal of Experimental Psychology: Human Learning and Memory, 1978, 4, 582-591.

This experiment demonstrated that people pay closer attention to, and recall more from, grammatically simple passages using common words. Subjects read 10 easy and 10 difficult passages. In the easy passages common words were used in short, grammatically simple sentences. The difficult passages included many rare words, and the sentences were long and grammatically complex. Performance on a concurrent secondary task carried out during reading indicated that more concentration was expended in reading easy, as compared to, difficult passages. Additionally, a subsequent test of topic recall indicated better memory for the content of easy passages.

Bruner, J. S., & Potter, M. C. Interference in visual recognitions, Science, 1964, 144, 424-425.

The relevance of this study to the area of classification was suggested by Posner (1973) in his book Cognition: An Introduction. This study can be interpreted as a demonstration that poor quality of information when items are first presented will retard subsequent classification. Bruner and Potter showed subjects pictures of complicated objects or scenes. The pictures were slowly brought to a predetermined point of focus, at which time subjects attempted to identify the picture. It was shown that the more the picture was blurred at initial introduction, the higher the probability that an incorrect identification would be made. Evidence from a subset of subjects who made verbal reports during picture presentation suggested an explanation. When more ambiguous or noisy information is initially provided, subjects attempt to make interpretations and later ignore contradictory information when the picture is brought into focus.

Daniel, T. C. Nature of the effect of verbal labels on recognition memory for form. Journal of Experimental Psychology, 1972, 93, 83-89.

This experiment demonstrated how people rely on "labels" when looking at and remembering objects. Subjects were told they were about to see a meaningful form, such as a dog. They were then shown a form that was a somewhat distorted silhouette of the object they expected to see. Subsequent recognition tests, using a range of forms that were more or less distorted, found that people selected forms that tended to resemble the label more than the shape originally seen. The experiment is consistent with the position that people selectively attend to the features of unfamiliar shapes that are consistent with suggested interpretations of the shapes.

De Rivera, J. Some conditions governing the use of the cue-producing response as an explanatory device. **Journal of Experimental Psychology**, 1959, **57**, 299-304.

This experiment demonstrated the interrelationship between two of the stated principles in facilitating comparison accuracy. It shows how specification of features, and specification of the allowable tolerance, can be interrelated factors. Three groups of subjects were trained to name ten very similar drawings that resembled fingerprints. Group 1 learned a different name for each drawing. Group 2 was told that all drawings were different, but learned one name for a set of five drawings and another name for the remaining set of five drawings. Group 3 was told that two sets of five drawings were similar in some way and taught the same names as Group 2. All groups then learned a different new name for each of the ten drawings. All groups learned these new names faster than a control group given no initial training. Thus, all three groups had learned to discriminate between the figures. However Group 1 was slightly better than Group 3 in this second phase of the experiment. In this case, when instructions stressed important features and practice required comparison at the level of tolerance later required, subsequent discrimination was superior to the case where both of these conditions were absent.

Dooling, D. J., & Lachman, R. Effects of comprehension on retention of prose. **Journal of Experimental Psychology**, 1971, **88**, 216-222.

This experiment demonstrated that an accurate preview of written material facilitates comprehension and later recall. Half of the subjects were supplied a title to a passage to be read, the other half were not. All subjects then read an ambiguously worded passage that was keyed to the title and then attempted to recall it. Comprehension and recall was superior when presentation of the title had preceded passage reading.

Dukes, W. F., & Bevan, W. Stimulus variation and repetition in the acquisition of naming responses. **Journal of Experimental Psychology**, 1967, **74**, 178-181.

This experiment demonstrated that presentation of several perspectives of an object during object-name training facilitates correct naming when testing involves various perspectives. Subsequent ability to name pictures of faces was compared between one group that was given four repetitions of a single facial pose, with another group that saw four different poses of the same face. They found that recognition of a particular pose was better following repetition, but that the group seeing four different poses did better in recognizing new poses.

Edmonds, E. M., & Mueller, M. R. Concept formation and utilization in the presence of irrelevant visual stimulation. **Psychonomic Science,** 1970, **18,** 109-110.

This experiment demonstrated that increased amounts of irrelevant visual information results in more difficult classification learning. Subjects attempted to learn to categorize a set of shapes (similar to histograms) by selecting one of six shapes displayed on each of 30 trials. The shapes displayed on each trial consisted of one experimenter-determined "histogram" shape and five dissimilar shapes used as distractors.

An added distraction was the amount of irrelevant visual information shown as a ratio of black to white background in the area of each shape used as a stimulus item. The area of each shape could be considered as a matrix with cells assigned to black or white shading. Level of irrelevant visual information was manipulated by changing color of a specified percentage of cells portrayed in the larger shapes from foreground black to background white. Different subjects were shown shapes that had 0, 15, or 25 percent of the cells portrayed in the shapes changed in this manner to represent zero, moderate, and high levels of irrelevant information, respectively. The ability of subjects to select the shapes defined as the category members during the 30 trials decreased as the amount of irrelevant information increased. Thus, irrelevant visual information of this type increased the difficulty of classification learning.

Ekstrand, B. R. Backward associations. **Psychological Bulletin,** 1966, **65,** 50-64.

This study is being cited as a typical example of the asymmetry of pair-wise associations following consistent pair-wise order in training. In this study paired-associate learning of A-B pairs was first conducted, where A was the member of the pair presented to subject as the stimulus and B was the correct response. Learning of the A-B association was then tested in one of two ways: (1) by presenting A and requiring recall of B, or (2) by presenting B and requiring recall of A. It was found that recall of A given B was less accurate than recall of B given A.

Ellis, H. C., Bessemer, D. W., Devine, J. V., & Trafton, C. L. Recognition of random tactile shapes following predifferentiation training. **Perceptual and Motor Skills,** 1962, **14,** 99-102.

This experiment supported the principle that specification of the degree of tolerance that can be allowed in comparisons facilitates subsequent accuracy in comparison. Subjects were forced to compare stimuli tactually. One group learned a different relevant name to each of eight shapes. A second group learned to respond by describing the four wide stimuli as "wide," the four narrow stimuli as "narrow." When later required to recognize the eight stimuli originally presented from among 16 other stimuli, accuracy was superior for the group that had learned eight different names. Thus, practice in distinguishing between objects, to the

degree that will be later required, facilitates subsequent ability to accurately distinguish previously presented objects from those in an unfamiliar set.

Ellis, H. C., & Muller, D. G. Transfer in perceptual learning following stimulus predifferentiation. **Journal of Experimental Psychology**, 1964, **68**, 388-395.

This experiment demonstrated the value of both subject-supplied "labels" and extensive training in learning to identify similar shapes. Prior to this experiment, several students were given a name for several simple (8-point) and several complex (24-point) polygons. This set of polygons and labels was then used in the experiment. During the first stage of the experiment, students either learned to pair the suggested name with each polygon, or simply observed the polygons. The number of learning trials for this stage was 2, 4, 8, or 16 for different groups of subjects. Subsequent memory for the complex polygons was found to be most accurate following training with the name. Thus, a label supplied by people prior to training can be useful in directing attention to the important features of an object. Additionally, memory performance was more accurate as the number of initial trials increased. (Note that attention to important features is a prerequisite to accurate classification. Therefore, such labeling should also facilitate classification learning.)

Ellis, H. C., & Shaffer, R. W. Stimulus encoding and the transfer of stimulus differentiation. **Journal of Verbal Learning and Verbal Behavior**, 1974, **13**, 393-400.

This article reported three experiments in which a type of predifferentiation training was followed by learning to pair names to previously studied stimuli. Experiment II in the series used shape-name pairs during identification training. It was found that learning names to shapes was easier following predifferentiation training if the shapes were similar, as compared to a control group not previously trained with the shape. However, if there was low similarity between shapes, learning to name shapes after predifferentiation training was more difficult when compared to the control group. It can be concluded that if there is some initial confusion between objects, symbols, or signals, initial comparison-training will facilitate subsequent identification training.

Englund, S. A. J., & Lundberg, I. Discriminative learning: Some restricting criteria and illustrative experiments. **Reports from the Psychology Laboratory, University of Stockholm**, 1963, No. 142.

This experiment demonstrated that practice in recognizing differences is essential to improvement in comparison training. Subjects were trained to compare the size of pairs of circles presented simultaneously. One group was always shown pairs of equal sizes, whereas a second group compared pairs of unequal sizes. Both groups had equivalent exposure to the range of sizes during

training. Comparisons by subjects after training indicated that only the group shown pairs of unequal sizes improved in their ability after training to discriminate among differences in size.

Fleishman, E. A., & Parker, J. F. Factors in the retention and relearning of perceptual-motor skill. **Journal of Experimental Psychology**, 1962, 64, 215-226.

This study demonstrated the high levels of retention that result from overlearning continuous motor skills. Subjects were trained in the performance of a pursuit task that required the manipulation of a hand lever and foot pedal. Fifty practice sessions, each seven minutes in duration, were required to achieve a level of learning which showed no further improvement in performance. Retention tests were then administered to separate groups of subjects 9, 12, and 24 months after training. Only the 24-month group showed any decrease in performance. But with three seven-minute practice sessions, recovery of previous performance was almost complete for the 24-month group.

Gagné, R. M., & Smith, E. C. A study of the effects of verbalization on problem-solving. **Journal of Experimental Psychology**, 1962, 63, 1-11.

This experiment demonstrated that requiring subjects to verbalize throughout the problem solving process facilitates learning to solve problems effectively. Subjects were required to solve the "pyramid puzzle," often referred to as the "Tower of Hanoi." While learning to solve this problem, some subjects were required to state a reason for each of their moves in solving the problem, whereas other subjects were not required to state the reason for their moves. It was found that subjects in the verbalization condition made fewer unnecessary moves but took more time in solving training problems, compared to those who had no such requirement. On a transfer problem where no subjects were required to explain their moves, subjects who had previously stated reasons performed much better, both in terms of fewer unnecessary moves and faster solution times.

Stating rationales is similar to the task element of selection in the current discussion of fault-finding and diagnosis. Thus, training in selection should be facilitated by requiring trainees to state their reasons for selecting from a set of alternative causes of equipment malfunction.

Gartman, L. M., & Johnson, N. F. Massed versus distributed repetition of homographs: A test of the differential-encoding hypothesis. **Journal of Verbal Learning and Verbal Behavior**, 1972, 11 801-808.

This experiment demonstrated that repetitions of homographs that are interpreted in more than one way can facilitate free recall of the words. Homographs were presented in a list of words to be remembered in which preceding words were used to bias subject interpretation. In one case the same context was used between

repetitions (e.g., INCH-FOOT...INCH-FOOT); whereas another condition changed the context between repetitions (e.g., INCH-FOOT...LEG-FOOT). Subsequent free recall of the homographs was three times greater in the changed condition, as compared to the unchanged condition.

Gibson, J. J., & Gibson, E. J. Perceptual learning: Differentiation or enrichment? **Psychological Review,** 1955, 62, 32-41.

This experiment is an example of subject participation in discrimination training. It demonstrated the importance of understanding both general and specific information required for discrimination. Subjects were encouraged to describe a shape shown to them. After presentation, the subject was asked to identify examples of the shape from a set of similar shapes. This process of showing one shape, having it described, then having identical shapes identified continued until only identical shapes were identified. An important finding of this study was that, as learning progressed, subjects first used general names followed by qualifying responses such as "thinner and rounder." Thus, identification of important features and feature characteristics is related to improvement in discrimination. Since the ability to accurately discriminate between similar objects is a prerequisite of accurate classification, participatory description should also facilitate classification training.

Glanzer, M., & Cunitz, A. R. Two storage mechanisms in free recall. **Journal of Verbal Learning and Verbal Behavior,** 1966, 5, 351-360.

This experiment demonstrated that delaying recall of a list of words has little effect upon memory for words, unless they were presented near the end of the list. Subjects were presented 15 words successively. After list presentation, subjects were required to wait up to 30 seconds before recalling the list, with the delay filled by an arithmetic or counting task. Words from the first portion of the list were recalled accurately, with little change related to delay. Words from the last portion of the list were recalled accurately immediately, but substantial decreases in accuracy were observed following a delay before testing.

Goldbeck, R. A., Bernstein, B. B., Hillix, W. A., & Marx, M. H. Application of the half-split technique to problem-solving tasks. **Journal of Experimental Psychology,** 1957, 53, 330-338.

This experiment demonstrated the value of training people for brief periods in general techniques that are often useful in selection of alternative solutions to investigate. These researchers used two electrical systems, one simple and one complex, in their experiment. The likelihood of malfunctions within each of these systems was equal for each component. When the likelihood of all malfunctions occurring is equally likely, the most efficient procedure is to split the system in half and check one half; whichever half is defective is split again, and so on. The

results of a training session showed that the half-split technique was quickly mastered in simple cases when each unit in the system was easily identifiable. However, mastery of the "half-split" technique was much more limited in the case of complex systems.

Goldin, S. E. Memory for the ordinary: Typical effects in chess memory. **Journal of Experimental Psychology: Human Learning and Memory**, 1978, **4**, 605-616.

This study demonstrated that typical, or common, well-known chess arrangements can be more accurately reconstructed than more unusual and interesting arrangements. Goldin had chess players representing various skill levels rate the degree to which they could understand the logic behind different configurations of chess pieces. A separate set of subjects was then shown each arrangement briefly and asked to reconstruct the position of the pieces on a chess board. Those configurations recognized as most typical and comprehensible were most accurately reconstructed.

Goldstein, M., & Rittenhouse, C. H. Knowledge of results in the acquisition and transfer of a gunnery skill. **Journal of Experimental Psychology**, 1954, **48**, 187-196.

This experiment demonstrated that providing knowledge of results that is not available in the operational setting can result in decrements in performance when the augmented feedback is withdrawn. Augmented feedback in the tracking task used by these researchers increased the accuracy of information available to subjects. After learning to track accurately with augmented feedback, withdrawal of augmented feedback led to less accurate tracking. The result suggests that training with an operational level of feedback should follow training with augmented feedback.

Haygood, R. C., & Bourne, L. E. Attribute and rule-learning aspects of conceptual behavior. **Psychological Review**, 1965, **72**, 175-195.

This article represented an attempt to identify the separate roles of attribute learning and rule learning in a series of concept identification experiments. Attribute learning is required in experiments with affirmative conceptual rules (for example, all red patterns would be categorized as representing the concept). Rule learning is required when more complex rules are used, for example all patterns which are red and not square are instances of the concept (exclusion rule). One finding particularly relevant for classification training principles is that subject knowledge of the type of rule used for a concept markedly reduced the number of trials required to reach concept attainment.

Heimer, W. L., & Tatz, S. J. Practice effects, knowledge of results and transfer in pitch discrimination. Port Washington, NY: NAVTRADEVCEN, Technical Report IH-52, 1966.

This study demonstrated the importance of including during training the comparisons that will be required in the operational setting. Subjects were trained to compare small differences in the frequency of tones within one of two ranges centered at either 800 cps or 3,000 cps. All groups improved during practice. However, when subjects trained on one range were tested on the other (i.e., trained at 800 cps and tested at 3,000 cps), it was found that accuracy in comparing different frequencies was no better than accuracy of a control group with a small amount of comparison practice.

Homa, D. & Coury, B. Perceptual selectivity and the fate of unemphasized information in a stimulus complex. **Memory & Cognition,** 1977, 5, 347-354.

This experiment demonstrated how stressing specific facial features affected subsequent recognition. Specific features, such as shape of eye, were remembered better when subjects were instructed to emphasize remembering that feature. It was found that subjects could remember emphasized features better at the cost of remembering the other features less well. Since recognition of important features is critical in classification, they should be emphasized during presentation.

Homa, D., Cross, J., Cornell, D., Goldman, D., & Shwartz, S. Prototype abstraction and classification of new instances as a function of number of instances defining prototype. **Journal of Experimental Psychology,** 1973, **101,** 116-122.

This experiment demonstrated that classifying a large number of category members results in better retention of classification skills. In the training phase of the experiment, subjects learned to classify dot patterns into three categories. During training, each category was represented by groups of three, six, or nine dots. The test for retention of classification skills was conducted either immediately or four days after training. During testing, subjects were required to sort both "old" dot patterns (those presented during training) and "new" dot patterns (those belonging to one of the three categories, but not presented during training). It was found that accuracy in classifying both old and new patterns was superior for categories represented by more examples during training, regardless of delay between training and testing.

Hull, C. L. Quantitative aspects of the evolution of concepts. **Psychological Monographs,** 1920, **28,** Whole No. 123.

In 1920, Clark Hull reported what was probably the first systematic investigation of human concept, or classification, learning. Hull used Chinese characters

as his stimuli, many of which are based upon a common element with additional features added to represent variations in meaning. The subject's task was to learn to classify the characters on the basis of the common element. The two major findings relevant to principles for classification training in this study were that emphasis of the common element in the characters facilitated learning (Hull colored the important feature of the character to emphasize it); and that it was found when subjects learned several classifications in succession, learning was facilitated by learning the easier problems first.

Hyman, R. On prior information and creativity. **Psychological Reports**, 1961, **9**, 151-161.

This study demonstrated that subject participation in evaluating their own solutions and those of others is an effective technique for improving problem-solving skills. Separate groups of subjects first tried to solve a difficult practical problem, such as developing methods to improve tourism in the U.S. After trying to solve the problem, different groups were required to criticize or constructively evaluate the proposed solutions. Subjects in groups who constructively evaluated the solutions of others and critically evaluated their own solutions were reported to improve the most.

Jacoby, L. J. On interpreting the effects of repetition: Solving a problem versus remembering a solution. **Journal of Verbal Learning and Verbal Behavior**, 1978, **17**, 649-667.

This article reported two experiments that can be cited in general support of the position that active attempts by a subject to construct an answer during training improves memory for solutions more than simply reading, observing, or hearing the correct answer. The results of Experiment I present the best evidence for this position. In this experiment, subjects read problems of the type found in crossword puzzles and either solved the problem or read the appropriate answer. In a subsequent test for recall of solutions using the same problems as test items, more words were remembered by the groups who constructed their answers than those who only read, observed, or heard the solutions. (Experiment II is not relevant to this discussion.)

Kantowitz, B. H. Interference in short-term motor memory: Interpolated task difficulty, similarity, or activity? **Journal of Experimental Psychology**, 1972, **95**, 264-274.

This experiment was an example of a parallel motor movement interfering with the acquisition of a discrete motor skill. Blindfolded subjects were trained to move a lever to a specified position. Immediately after training, the subjects were required to move the lever randomly during a 20-second delay. After the 20-second delay, subjects again moved the lever to the specified position. Measurement of accuracy later clearly indicated a decrement in performance caused by the

interference (random movement) during the 20-second delay between training and testing.

Kincade, R. G. A differential influence of augmented feedback on learning and on performance. USAFWADS Tech. Rep., 1963, 38, 239-244.

This experiment demonstrated the relationships between feedback (always available from the equipment operation only) and augmented feedback provided during training affecting motor skill learning, and subsequent performance without augmented feedback.

Kincade had subjects learn a continuous pursuit task with feedback provided on a clear or "noisy" display. Half the subjects in each of the display feedback conditions were given additional feedback; the other subjects received no additional feedback. The groups with augmented feedback had fewer errors. When augmented feedback was withdrawn, tracking accuracy decreased for the group with the noisy display. However, for the control group trained without noise and augmented feedback, accuracy was better than that of the group trained on the same display with augmented feedback.

Kurtz, K. H. Discrimination of complex stimuli: The relationship of training and test stimuli in transfer of discrimination. Journal of Experimental Psychology, 1955, 50, 283-291.

This experiment demonstrated that learning different names for complex, but similar, shapes is easier when subjects first learn to discriminate between the components comprising the shapes. The stimuli used in this experiment consisted of different sets of stimuli, with each set member composed of the same set of geometrical components. Subjects first learned to discriminate between members from each of several sets of these complex shapes. Subjects were later required to learn names for members and sets of shapes that varied by components and combinations of components. Some of these variations had been presented during discrimination training—some not.

The results of the experiments suggested that learning to discriminate between shapes on the basis of specific characteristics will only help people learn names for objects that differ from one another on the basis of those learned characteristics.

Leonard, J. A., & Conrad, R. Maintenance of high accuracy without augmented feedback. Nature, 1963, 199, 512-513.

This experiment demonstrated that withdrawal of knowledge of results following training in a simple motor skill does not necessarily result in a performance decrement. Subjects were taught an arbitrary association between

keys on a keyboard and letters called out by an instructor. After all subjects had achieved error-free performance during training with knowledge of results, subsequent performance during a 40-minute session on each of the following eight days showed no increase in errors and an increase in speed. This finding suggests that knowledge of results is not critical for sustaining all types of motor learning. However, it should be noted that performance accuracy in this task is primarily dependent upon memory for arbitrary associations.

Light, L. L., & Carter-Sobell, L. Effects of changed semantic context on recognition memory. **Journal of Verbal Learning and Verbal Behavior**, 1970, **9**, 1-11.

This experiment demonstrated that the ability to recognize a word can be impaired if the context in which the word is presented changes in the period between study of the word and subsequent recognition testing. Homographs were paired with one adjective at the time of study (e.g., soda cracker) and later shown in a recognition test paired with the same adjective, or with an adjective that suggested a different meaning of the homograph (e.g., safe cracker). Recognition was better when the same adjective was paired with the target word even though the subjects knew that only recognition of the noun was being tested.

Lorge, L., & Thorndike, E. L. The influence of delay in the after-effect of a connection. **Journal of Experimental Psychology**, 1935, **18**, 186-194.

This experiment was an early demonstration that delay of knowledge of results in learning a discrete motor skill does not impede learning. Subjects tossed balls over their heads at an unseen target behind them. Knowledge of results was given by reporting the distance of each throw from the target. Delay periods between the ball landing and accuracy report were 0, 1, 2, 4, and 6 seconds, respectively. Reaching criterion was found to be comparable for all delays.

Madigan, S. A. Interserial repetition and coding processes in free recall. **Journal of Verbal Learning and Verbal Behavior**, 1969, **8**, 828-835.

This experiment demonstrated that having people interpret words in different, but similar, ways results in better recall of the words than simple repetition. Subjects were presented a list of cue word-target pairs. Some pairs were shown once in the list, some pairs were repeated twice, and other pairs were altered (e.g., fever-CHILL versus snow-CHILL) between repetitions. Twice-presented words were subsequently recalled better than once-presented words. Target words in the altered condition were better recalled than words in the unaltered condition. Additionally, target words in the altered condition were better recalled if the number of items intervening between repetitions was minimized.

Madigan, S. A., & McCabe, L. Perfect recall and total forgetting: A problem for models of short-term memory. **Journal of Verbal Learning and Verbal Behavior,** 1971, **10,** 101-106.

This experiment demonstrated the interrelationship between list position and time of testing in paired-associate learning. Subjects were shown five word pairs, with immediate testing of one pair by presentation of the first member of each pair. After 50 lists of five word pairs, subjects were tested for memory of all 250 pairs. Pairs in the first two positions were remembered correctly 20% of the time; whereas no pairs that were the last member of five-pair lists were remembered.

Mandler, J. M., & Parker, R. E. Memory for descriptive and spatial information in complex pictures. **Journal of Experimental Psychology: Human Learning and Memory,** 1976, **2,** 38-48.

This experiment demonstrated the effect of spatial organization upon memory for object location. Subjects studied line drawings of either real-world scenes containing identifiable objects in typical contexts, or portrayals of the objects depicted in atypical contexts in the real-world scenes. It was determined that subjects had expectations concerning the vertical, but not horizontal, position of objects in these pictures. Organization of the pictures had little effect on accuracy of memory for size, orientation, or physical appearance of objects in the pictures. However, memory for both expected position (vertical) and unexpected position (horizontal) of objects was much better if typical, rather than atypical, pictures had been studied.

Martin, C. J., & Saltiz, E. Serial versus random presentation of paired-associates. **Journal of Experimental Psychology,** 1963, **65,** 609-615.

This study demonstrated that random presentation of items does not reduce the total number of items remembered in paired-associate learning. Subjects studied a list of word pairs with item order the same on every study trial or randomized on every trial. There was no significant difference in the number of items remembered after either five or ten trials between the two presentation conditions. In fact, there was a trend for subjects to remember more, following randomized order presentation.

Matthews, L. Response latency as a function of free choice or fixed postfeedback interval in concept identification. **Psychonomic Science,** 1972, **29,** 238-240.

This experiment demonstrated that delays after knowledge of results can be valuable in categorization learning. The number of trials necessary to successfully complete a concept identification task was compared for subjects with different time constraints placed upon them following a decision. Half of the subjects were only allowed two seconds between knowledge of results and the next trial; whereas

the other subjects were allowed to control this period. Subjects who were allowed to control the period between knowledge of results and the next trial learned to classify the stimuli in fewer trials than the two-second group.

Mengelkoch, R. F., Adams, J. A., & Gainer, C. A. The forgetting of instrument flying skills as a function of the level of initial proficiency. U.S. Naval training device Center, **Human Engineering Tech. Rep.** NAVTRADEVCEN 71-16-18, September 1958.

This study reported the relationship between initial skill level of discrete motor tasks and retention over a four-month delay interval. Subjects were trained to perform discrete tasks in a cockpit to either low or high skill levels. Subsequent performance in tests four months later was sufficiently degraded to impair flying efficiency and safety. Forgetting was found to be greater following low levels of initial training. It should be noted, however, that retraining required less time than initial training.

Neimark, E. D. Effect of differential reinforcement upon information-gathering strategies in diagnostic problem solving. **Journal of Experimental Psychology**, 1967, **74**, 406-413.

This experiment demonstrated that training in successful problem-solving using optimal evaluation strategies facilitates the use of these strategies. Neimark devised a special problem board with shutters that could be moved aside to disclose diagnostic information underneath. Information was arranged in different patterns so that certain moves would represent a "safe" information-gathering strategy and others a gambling strategy. The "safe" strategy for this device eliminates half the alternatives with each move and thus provides complete information with the least average number of moves. The gambling strategy is a move that might uncover needed information on the first move. The experimenter controlled the proportion of problems on which gambling would be successful by manipulating the information revealed. Analysis of the first moves on successive problems indicated that subjects were able to profit by their expeience in this situation and to formulate strategies, or rules, of selection to rationally guide their moves. Those subjects who were never reinforced for gambling soon developed a safe strategy; whereas those who found that their gambling moves frequently paid off leaned toward a gambling strategy.

Olton, R. M., & Crutchfield, R. S. Developing the skills of productive thinking. In G. A. Davis & J. A. Scott (Eds) **Training creative thinking.** Huntington, NY: Robert E. Krieger Publishing Company, 1978.

This research demonstrated improvement in students' ability to generate alternative solutions to a problem after practicing generation of solution alternatives with related problems. In the study, modeling of generation of alternatives

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involved deferring evaluation by the experimenter and separate consideration of each of the symptoms of the problem. The training also stressed class participation in generating alternative solutions to the problems. The researchers compared a group of elementary students trained with a control group that was presented the same problems in an unstructured setting prior to, just after, and six months after training. A large increase in the production of relevant alternatives was observed immediately after training for the students in the experimental condition. This superiority in generation over the group of control subjects was still evident six months after training had ceased.

Pfafflin, S. M. Stimulus meaning in stimulus predifferentiation. **Journal of Experimental Psychology,** 1960, **59,** 269-274.

This experiment demonstrated that learning relevant names for shapes helps people to later learn or to discriminate between the named shapes. Three sets of 10 shapes were selected so that the sets differed in meaningfulness (assessed previously). Subjects were first required either to observe (one set of) the shapes to learn relevant or irrelevant labels for the shapes, or were given no pretraining in labeling the shapes.

In a later discrimination learning phase, subjects responded to a presentation of each shape in the set. Subjects in the relevant label and observation groups made fewer discrimination errors than subjects in the irrelevant label group. In addition, among the groups that had been shown shapes rated low in meaningfulness, the group trained with relevant labels made more correct discriminations than any other group that had been shown the same shapes.

Posner, M. L, & Keele, S. W. On the genesis of abstract ideas. **Journal of Experimental Psychology,** 1968, **77,** 353-363.

This series of experiments illustrated the value of using a variety of stimuli during classification training. The major concern of the experiments was to investigate if classification training with a large range of category members resulted in better classification of items with a similar range. Results indicated that: (1) training with a wide range of category members resulted in better subsequent categorization of "new" members with a wide range; and (2) training with feedback did not increase rate of learning how to classify, but when subjects had been given feedback during training, later categorization was better.

Ranken, W. C., & Evans, S. H. Facilitation of schematic concept formation as a function of two within-schema pretraining modes. **Pyschonomic Science,** 1968, **13,** 325-326.

The experiment demonstrated the value of comparing objects or signals during classification training. The effect of two types of classification training on later

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classification ability was compared with no training. One type of training involved drawing abstract figures. The other type of training involved ranking, or scaling, the similarity between figures. Later classification of "new" figures from the same sets demonstrated that training in ranking resulted in the best classification learning, followed by drawing next, and no training last.

Reder, L. M., Anderson, J. R., & Bjork, R. A.   A semantic interpretation of encoding specificity. Journal of Experimental Psychology, 1974, 102, 648-656.

The results of these experiments suggest that changes in word modifiers between study and test impair memory performance because they alter the meaning of the test word. The effect was assessed of these changes on memory of words with high and low word frequency of use, as counted in a general sample of publications.   The primary finding in this article was that changes in context between study and test were more effective in reducing cued recall of high frequency words, as compared to low frequency words.

Richardson, A.   Mental practice: A review and discussion: II.   The Research Quarterly, 1967, 38, 263-273.

This article reviewed 11 studies of the effect of observation of the task and mental practice on motor skill learning. The studies reviewed included such skills as the tennis forehand and backhand drive, dart throwing, card sorting, and juggling. The results were difficult to interpret as a result of confounding in design and lack of statistical analysis. However, the author concluded that the studies generally supported the view that observation of the task and mental practice could result in improved performance.   Additionally, it was concluded that a combination of observation, mental practice, and motor skill practice resulted in maximum improvement during skill learning.

Rimland, B. Effectiveness of several methods of repetition of films. Washington, DC: Office of Naval Research, Special Devices Center, Tech. Rept. 269-7-45, 1955.

This study demonstrated the value of a thorough presentation of a motor task prior to practice.   One investigation made was the effect of one or two presentations of a film demonstrating knot-tying, prior to practice of the task. It was found that two presentations prior to practice led to the fastest acquisition of the skill. It was also concluded that an adequate understanding of the task was a prerequisite to efficient skill training.

Rosenberg, S. The recall of verbal material accompanying semantically well-integrated and semantically poorly-integrated sentences. **Journal of Verbal Learning and Verbal Behavior**, 1969, **8**, 732-736.

This experiment demonstrated that recall of information in semantically well-integrated sentences is better recalled than material in semantically poorly-integrated sentences. Well integrated sentences consisted of more common relationships (i.e., thief stole the money) than poorly integrated sentences (i.e., thief passed the wagon). Both types of sentences contained the same type of critical information (i.e., "The thief who **delivered the tape** stole the money" versus "The thief who **delivered the tape** passed the wagon.") After all sentences had been read, subsequent memory tests found better recall for critical information embedded in well integrated sentences.

Saltz, E. Compound stimuli in verbal learning: Cognitive and sensory differentiation vs. stimulus selection. **Journal of Experimental Psychology**, 1963, **66**, 1-5.

This experiment is consistent with the principle that accurate specification of the features or characteristics to be compared can improve discrimination learning—particularly when comparisons are based upon more than one feature or characteristic. Subjects learned to respond to differences between words, colors, or words printed in different colors. Accuracy during training was lowest for colors, moderate for words, and highest for colored words. The use of both word and color resulted in more accurate comparison than use of either feature alone. The finding suggests that attention to a subset of all relevant features may retard comparison training. Consequently, specifying relevant features only could facilitate training.

Smallwood, R. A. & Arnoult, M. D. A comparison of simple corrections and functional feedback in schema learning. **Perception & Psychophysics**, 1974, **15**, 581-585.

This experiment demonstrated the importance of providing useful information when giving knowledge of results during category learning. Three types of classification training were used: no knowledge of results, simple correction by stating the correct classification, and functional knowledge of results. In functional knowledge of results a transparency of the central category member, or prototype, was placed over a figure if it had been incorrectly classified. Both training and later classification of new figures was better following training with functional knowledge of results. No differences between the simple knowledge of results and the no knowledge of results training conditions were found.

Stasz, C, & Thorndyke, P. W. **The influence of visual-spatial ability and study procedures on map learning skill.** Santa Monica, CA: The Rand Corporation, Technical Report N-1501-ONR, June 1980.

This study was a replication and extension of the work reported by Thorndyke and Stasz (1980). The previous study data were used in the present work to identify strategies for learning "location" that consistently improved performance. In this study, the authors identified four effective learning procedures: imagery, pattern encoding, planning, and evaluation.

Stein, B. S., Morris, C. D., & Bransford, J. D. Constraints of effective elaboration. **Journal of Verbal Learning and Verbal Behavior,** 1978, 17, 707-714.

Experiment II in this article demonstrated that additional information about material being studied must be relevant if it is to facilitate subsequent recall. Subjects read three types of sentences: (1) non-elaborated (e.g., "The child was comforted by the short man"), (2) precisely elaborated (e.g., "The child was comforted by the short man who looked the child in the eye"), and (3) imprecisely elaborated (e.g., "the child was comforted by the short man who sat around a lot"). Subsequent recall of the target words (e.g., short) was best for precisely elaborated sentences, moderate for non-elaborated sentences, and worst for imprecisely elaborated sentences. It was further demonstrated that these results were not due to differential rates of guessing. The results not only demonstrate the value of relevant elaboration, they also demonstrate that irrelevant elaboration of material may reduce its capacity for being recalled.

Suchman, J. R. The child and the inquiry process. In A. H. Passow & R. R. Leeper (Eds.), **Intellectual development: Another look.** Washington, DC: Assoc. Supervision & Curriculum Development, 1964.

This study is an example of facilitating generation of alternatives by encouraging questions and providing prompt, reasonable answers. Suchman presented films of a physics demonstration to school children who were encouraged to discover the underlying principles involved in the demonstration. The students were encouraged to ask questions and were provided prompt, reasonable answers to their questions. Taped records of the childrens' questions were analyzed for content by the researchers and also played back to the students for their own evaluation. In comparison with groups who were simply shown the film demonstration, those exposed to what Suchman calls Inquiry Training asked more questions of generally higher quality. Specific questions requiring the instructor to do the thinking became less frequent after this training, and those concerned with the alternative factors in the problem became more frequent.

Taylor, A., & Noble, C. E. Acquisition and extinction phenomena in human trial-and-error learning under different schedules of reinforcing feedback. **Perceptual and Motor Skills**, 1962, 15, 31-44.

This experiment demonstrated the importance of providing knowledge of results to subjects following every completion of a task during training. Skill acquisition and retention in a motor skills task were compared for subjects receiving knowledge of results on 100, 75, 50, or 25 percent of the learning trials. Acquisition of the skill to be learned was best for the group who received 100 percent feedback. They reached criterion more quickly than the other groups. Retention was somewhat poorer for the 100% group during early stages of training, but this trend was confined solely to the early trials.

Taylor, D. W., & Faust, W. L. "Twenty questions": Efficacy in problem solving as a function of size of group. **Journal of Experimental Psychology**, 1952, 44, 360-368.

This experiment was an example of improvement in problem-solving ability of subjects when training was continued until the problem was solved. Subjects were allowed up to 30 questions per game in a modified version of the game of "Twenty Questions." Subjects continued to improve in their ability to solve the problems set over the 16 permitted trials.

Thios, S. J. Memory for words in repeated sentences. **Journal of Verbal Learning and Verbal Behavior**, 1972, 11, 789-793.

This experiment demonstrated that recall can be made easier by repeating words in similar contexts. Word pairs were presented in sentences twice during presentation of the entire set. In the "same" condition, the same sentence was presented twice. In the "similar" condition the word pairs were presented in two sentences that did not change the meaning of the word pairs. In the "different" condition, a different interpretation of the two words was presented for the two presentations. Words presented in the "similar" condition were later recalled more often than words in either the "same" or "different" conditions. Thus, slight changes in the way people think about material helps them to remember it.

Thorndyke, P. W., & Stasz, C. Individual differences in procedures for knowledge acquisition from maps. **Cognitive Psychology**, 1980, 12, 137-175.

This study identified learning strategies of subjects who were requested to "think aloud" while studying a map prior to being given a number of memory tests for location and route finding. By contrasting the verbal protocols of good and poor learners, the authors identified six effective learning procedures: partitioning, imagery, memory-directed sampling, pattern encoding, relation encoding, and evaluation.

Underwood, B. J. Degree of learning and the measurement of retention. **Journal of Verbal Learning and Verbal Behavior**, 1964, **3**, 112-129.

This report of paired associate learning demonstrated that increased amounts of practice after initial acquisition continue to benefit subsequent retention. Initial training in memorization of eight nonsense syllable-adjective pairs was given to four groups of subjects. The four groups were respectively required during the training to recall a list of work pairs 8, 9, 10, or 11 times correctly. After 24 hours had elapsed, the groups were tested for their retention factor related to their (training) recall factor. For one list, with an eight or nine recall score during training, correct recall after 24 hours delay was scored 80 percent. Similarly, with a 10 or 11 recall score during training, correct recall after 24 hours delay was scored at 95 percent. Thus, even after 100 percent performance during training, further practice will improve retention when testing is delayed for 24 hours.

Whimbey, A. Teaching analytical reasoning in mathematics. In J. Lockhead & J. Clement (Eds.), **Cognitive process instruction.** Philadelphia: The Franklin Institute Press, 1979.

These authors reported gains in problem-solving skill when training consisted of practice in vocalizing problems and transition from easy to difficult problems. University students were trained to solve written analogical reasoning problems. Training was characterized as (1) requiring students to state the problem, alternative solutions, and their evaluations of those solutions; and (2) involving a progression from easier to more difficult problems.

A comparison of scores on simple analogical arithmetic problems prior to, and after, training demonstrated a significant reduction in the number of errors by these students.

Wollen, K. A., Weber, A., & Lowry, D. H. Bizarreness versus interaction of mental images as determinants of learning. **Cognitive Psychology**, 1972, **3**, 518-523.

This experiment demonstrated that it is the interactive quality of images, rather than any bizarre quality, that facilitates recall of verbal material. Pairs of words, along with one of four types of pictures depicting the objects: (1) non-interacting, non-bizarre; (2) non-interacting, bizarre; (3) interacting, non-bizarre; and (4) interacting, bizarre were presented to subjects. For example, in the interacting cases involving the words cigar and piano the non-bizarre picture showed a cigar resting on the edge of a piano and the bizarre picture showed a cigar protruding from under the keyboard of a piano. Word recall tests indicated benefits for retention when elements of the picture interacted in a nonbizarre way; whereas bizarreness was found to affect recall adversely, when compared to a control group not shown any pictures.